International Journal of
Environmental Research and Public Health

Disasters Preparedness and Emergency Response

Prevention, Surveillance and Mitigation Planning

Edited by
Mariusz Goniewicz

Printed Edition of the Special Issue Published in
International Journal of Environmental Research and Public Health

www.mdpi.com/journal/ijerph

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Disasters Preparedness and Emergency Response: Prevention, Surveillance and Mitigation Planning

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Editor

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This is a reprint of articles from the Special Issue published online in the open access journal *International Journal of Environmental Research and Public Health* (ISSN 1660-4601) (available at: https://www.mdpi.com/journal/ijerph/special_issues/Disasters_Preparedness_Emergency_Response_Prevention_Surveillance_Planning).

For citation purposes, cite each article independently as indicated on the article page online and as indicated below:

LastName, A.A.; LastName, B.B.; LastName, C.C. Article Title. *Journal Name* **Year**, *Volume Number*, Page Range.

ISBN 978-3-0365-6055-7 (Hbk)
ISBN 978-3-0365-6056-4 (PDF)

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International Journal of
Environmental Research and Public Health

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Article

Generating High-Granularity COVID-19 Territorial Early Alerts Using Emergency Medical Services and Machine Learning

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Abstract: The pandemic of COVID-19 has posed unprecedented threats to healthcare systems worldwide. Great efforts were spent to fight the emergency, with the widespread use of cutting-edge technologies, especially big data analytics and AI. In this context, the present study proposes a novel combination of geographical filtering and machine learning (ML) for the development and optimization of a COVID-19 early alert system based on Emergency Medical Services (EMS) data, for the anticipated identification of outbreaks with very high granularity, up to single municipalities. The model, implemented for the region of Lombardy, Italy, showed robust performance, with an overall 80% accuracy in identifying the active spread of the disease. The further post-processing of the output was implemented to classify the territory into five risk classes, resulting in effectively anticipating the demand for interventions by EMS. This model shows state-of-art potentiality for future applications in the early detection of the burden of the impact of COVID-19, or other similar epidemics, on the healthcare system.

Keywords: COVID-19; machine learning; health geomatics; geographic information system; emergency medical services; spatial filtering; geo-AI; resources management

Citation: Gianquintieri, L.; Brovelli, M.A.; Pagliosa, A.; Dassi, G.; Brambilla, P.M.; Bonora, R.; Sechi, G.M.; Caiani, E.G. Generating High-Granularity COVID-19 Territorial Early Alerts Using Emergency Medical Services and Machine Learning. *Int. J. Environ. Res. Public Health* **2022**, *19*, 9012. https://doi.org/10.3390/ijerph19159012

Academic Editor: Paul B. Tchounwou

Received: 14 June 2022
Accepted: 21 July 2022
Published: 25 July 2022

1. Introduction

Even before the pandemic of COVID-19, the potential central role of data science in infectious disease forecasting and outbreak science was already recognized [1]. In the last two years, the worldwide scientific community has made unprecedented efforts to mitigate the effects of the COVID-19 pandemic, focusing on the application of cutting-edge technologies related to data science: artificial intelligence (AI), machine learning (ML), and big data analytics were considered key assets in extracting information useful to fight the pandemic [2–8]. Despite the fact that the worst phase of the emergency seems to have passed thanks to the availability of vaccines, it is likely that healthcare systems will have to pay special attention for many years to come to monitor and quickly detect possible events of local recrudescence due to new COVID-19 variants.

Different strategies with three different time horizons have been proposed [3]: (1) the rapid identification of outbreaks and the diagnosis of cases (short-term); (2) the identification of therapeutic options (medium-term); (3) the development of resilient smart cities (long-term). Similarly, the monitoring, surveillance, detection, prevention, and mitigation

of indirect effects were identified as goals for applying new technologies, such as big data, AI, the Internet of Things (IoT), and blockchains [7] in public health. In the long term, the use of such tools could represent a unique opportunity to trigger a paradigm shift capable of supporting future policies in public health and medicine.

The spreading of a pandemic is inherently a spatial phenomenon. Coherently, in a recent systematic review [9], a specific focus on different studies that conducted spatial analysis in relation to COVID-19 was explored, in which the following aspects were identified:

1. Spatiotemporal analysis: a descriptive and/or predictive modeling of the evolution of the pandemic within a certain territory (usually at the national and regional level) was explored using official data on positive cases, often also considering people's mobility, with examples relevant to China [10], South Korea [11], the USA [12], and Italy [13].
2. Health and social geography: the relationship between the virus spreading (based on confirmed cases) and healthcare resources [14], such as nurses [15] or surgeons [16], was explored together with the correlation between confirmed cases and demographic and/or socio-economic characteristics [17,18].
3. Environmental variables: the correlation between confirmed cases and environmental factors, mainly climatic variables [19], such as humidity and temperature [20], was inspected.
4. Data mining: different analyses were performed in relation to additional and alternative data sources, such as mobility [21,22] and flights [23], to corroborate spatial analysis.
5. Web-based mapping: web services implemented to easily visualize and facilitate the comprehension of the obtainedresults.

From this review, the potentialities of geographic information systems (GIS) as a set of tools for capturing, storing, checking, manipulating, analyzing, and displaying spatially georeferenced data to handle the geospatial component of the pandemic analysis, also at the local level, were highlighted, as in other studies [24–26]. In a recent update of this review [27], including 221 papers published in only one year, the importance of data quality, in terms of both availability and spatial-temporal granularity, was underlined, to allow the unveiling of new explicative patterns in the spreading of COVID-19, with higher informative content towards decision-making at the local level. From these reviews, the combination of spatial analysis and data science (mostly AI and specifically ML) has emerged as the best pathway to build descriptive and predictive models to monitor the evolution of the COVID-19 pandemic.

In the recent literature (see Table 1), the implementation of AI predictive models to foresee the evolution of COVID-19 curves in a certain territory has received consistent attention [26,28–33], with a specific focus on support for decision-making to implement public health policies [28]. The use of AI methods is recognized as able to outperform the classical statistical models (such as the Susceptible–Exposed–Infectious–Recovered SEIR model) in short-term forecasts [29]. However, some issues still remain unsolved:

- All the considered models rely on official diagnosis data, which are characterized by significant confounding factors, such as testing capabilities, logistics, data communication flows, and people's behavior.
- The geographic resolution of the models remains low, considering whole countries [26,28–31] or at least large administrative areas [32,33]. A low granularity can consistently limit the effectiveness of models as decision support for policymakers [32].
- Spatial mapping usually results in a slow generating process [28,31] and therefore is difficult to keep updated and not usable to guide day-by-day activities.

These limitations were addressed in this study by implementing different strategies. Regarding the data source, we previously demonstrated [34] how the geo-localized collection of calls to the emergency medical number and consequent ambulance dispatches by the Emergency Medical Services (EMS) could be considered as an alternative source of information to monitor the epidemic spreading across a territory, as also assessed in

previous studies [35–40], thus overcoming the intrinsic limitations of the official diagnosis data [8,41–44], in particular during the first pandemic wave [45]. However, this kind of data was never used, to the best of our knowledge, to implement territorial predictive models. Moreover, EMS data are simple, low in weight, and widely collected, guaranteeing their quick usability, fast processing (thus overcoming the slowness of spatial mapping [28,31]), and high replicability in different territories.

Table 1. Main relevant features of similar studies in the scientific literature.

	Target Variable	Data Source	Max Geographic Granularity	Algorithm Selected	Performance Evaluation
Mollalo et al., 2020 [26]	Cumulative incidence	Socioeconomic, behavioral, environmental, topographic, and demographic factors	County	Multi-Layer Perceptron (MLP)	RMSE = 0.72
Hussein et al., 2022 [28]	Daily infected cases	Official diagnoses	Country	Time-Delay Neural Network (TDNN)	RMSE = 1.15
Alsayed et al., 2020 [29]	Epidemic peak, infected cases	Official diagnoses	Country	Susceptible–Exposed–Infectious–Recovered (SEIR) model, Adaptive Neuro-Fuzzy Inference System (ANFIS)	Normalized RMSE = 0.041
Singh et al., 2020 [30]	Cumulative cases, deaths, recoveries	Official diagnoses	Country	AutoRegressive Integrated Moving Average (ARIMA)	Akaike information criterion value = 20
Hussein et al., 2021 [31]	Daily infected cases	Official diagnoses	Country	Linear forecast model + custom mathematical equation	RMSE = 2.15
Lynch et al., 2021 [32,33]	Cumulative cases	Official diagnoses	County	Moving Average (MA)	MdAE = 0.67
Friedman et al., 2021 [36]	Excess out-of-hospital deaths, respiratory complaints, oxygen saturation level of patients	Emergency Medical Services (EMS) data	City	Comparison against Linear Continuous Fixed Effect	Not applicable
COVID-19 APHP-Universities-INRIA-INSERM Group, 2020 [37]	Requirements for ICU beds	EMS data, positivity ratio, emergency department visits, hospital admissions	Region	Correlation curve analysis	R^2 = 0.79–0.99
Levy et al., 2021 [38]	Hospitalizations	EMS data	State	AutoRegressive Integrated Moving Average (ARIMA)	AIC
Xie et al., 2021 [40]	EMS demand	Hospitalizations	County	Time series regression	R^2 = 0.85
Our study	Territorial alert level	EMS data	Municipality	Random Forest (RF)	Accuracy = 80%

Despite the fact that other causes could have contributed to the increase in the number of these events (such as, for example, seasonal flu), the volumes that characterized COVID-19 waves were significantly different [46], so the impact of regular EMS baseline activity for other respiratory or infective issues could therefore be neglected. This kind of approach could also be important in the upcoming scenario, in which we are witnessing progressively decreasing preventive measures towards virus diffusion, which may result in a lower level of population screening and the abrupt local spreading of the disease.

With relevance to the geographic granularity, the limit to overcome is the low statistical meaningfulness of models focusing on small areas in terms of resident population, so that

a certain level of aggregation is necessary to identify actual patterns in the data rather than random noise. To solve this issue, a new custom method for spatial aggregation is here proposed, based on drive-time distance and linear spatial filtering, which allows for reaching a meaningful size in terms of population while still keeping a spatial focus on the central point of the aggregated cluster, i.e., a single municipality as a target, regardless of its dimension.

In accordance with the conducted analysis, we hypothesized that the implementation of data science methods, applied to the georeferenced database of calls and vehicles dispatched by EMS for respiratory and infective causes, could be used to infer early alert monitoring relevant to the COVID-19 spatio-temporal evolution, with anticipation, higher granularity, and more reliability compared to official infection data. In our previous study [34], we already demonstrated the possibility to identify the timing points of change in the shape of the curves of EMS dispatches across different districts, evidencing the possible start of epidemic growth. To further exploit the proposed framework in the direction of providing support for decision-making, in this study our aim was to develop and validate a continuous monitoring model, based on ML methods with supervised learning, for the day-by-day analysis of the evolution of EMS data, in order to generate an 'early-alert' COVID-19 system with a higher level of geographic granularity (single municipalities instead of districts with 100,000 residents), to promptly identify the occurrence of new hotspots across the analyzed territory. The main novelties introduced are:

- The use of a proxy data source—EMS data instead of official swab tests—characterized by a smaller time lag for communication and processing, less dependent on people's behavior, available infrastructures (also for information flow), and already automatically collected.
- A high geographic granularity (single municipalities), obtained through spatial processing methods.
- A simple and agile architecture, both in the data structure and in the computing algorithm, which allows fast execution and daily updates to the model.

The implementation relies on the retrospective data collected by EMS relevant to the Italian region of Lombardy (with a population of 10.06 M inhabitants over a surface of 23,844 km^2), the first area outside of China to record an outbreak of COVID-19.

2. Materials and Methods

2.1. Model Development and Optimization

In order to apply supervised ML to tackle a classification problem, the following steps were identified:

I. Definition of the target variable: the class-defining label that the algorithm must assign to each record;
II. Identification of the explicative attributes: measurements on which the classification is based;
III. Identification of the main computational block: ML classification algorithm to be trained and subsequently applied;
IV. Definition of a post-processing algorithm, aimed at elaborating the output of the main computational block in order to enhance the representativeness and usability of the output.

To this aim, the methodology and the output of our previously published descriptive model [34] were exploited to define a binary label (step I) corresponding to the active spreading or no diffusion of COVID-19 in a specific territory. More specifically, after dividing the Lombardy region into 77 districts of approximately 100,000 residents, for each district, the time series representing the number of vehicles dispatched by the EMS (normalized by the resident population) for respiratory or infective issues was analyzed to automatically define a first inflection point, representing an estimate of the start of the pandemic spread. This operation was performed using a previously validated signal

processing algorithm suited for the identification of inflection points for curves with noise superimposed [47]. Briefly, it is based on a geometrical criterion in which a trapezium is built on the time series and, iteratively, one vertex is moved over time: the position of such a vertex characterized by the maximal trapezoid area is considered as the inflection point. Data preceding this point were labeled as '0' (no diffusion) while data following it were labeled as '1' (active spreading), as represented in Figure 1. To enhance the informative content within the training set, in addition to our previous analysis focused only on the period from 1 January to 23 March 2020, the data relevant to the following waves of the pandemic in Lombardy were also considered. Moreover, the ending points of the waves were also identified by applying the same algorithm to the reversed data. In this way, the final training set was composed of a total of 58,190 daily records, randomized and composed of a balanced share of the two classes, spanning from 1 January 2020 to 13 March 2022 (802 days).

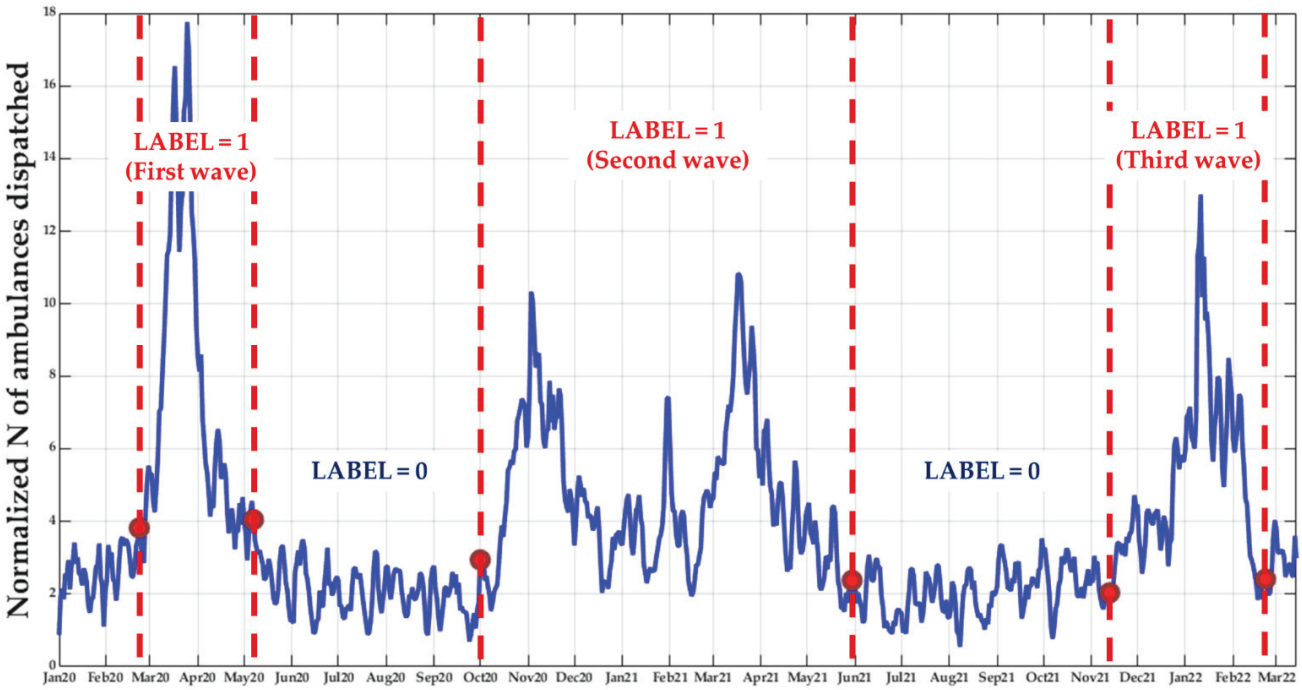

Figure 1. Subdivision of the time series, representing the vehicles dispatched by EMS for respiratory and infective issues (normalized by the resident population) in a certain territory, in periods where a label (0 = 'no diffusion'; 1 = 'active spreading') was assigned to each point generated, according to the automated identification of inflection points (change in the shape of the data, see [34] for more details).

The next step (II) is the identification of the explicative attributes, the features to be computed and associated with the label of each day, on which the algorithm will perform the classification. For this purpose, the series of unfiltered data relevant to both the daily calls to the EMS number and the daily dispatches of EMS vehicles, relevant to respiratory and infective causes, normalized by the resident population in the district under analysis, were considered. This choice was supported by the very high correlation of both the number of ambulances dispatched ($r^2 = 0.81$) and emergency calls ($r^2 = 0.96$) with official casualties at the province level (the official data with the highest granularity available) due to COVID-19 during the first pandemic peak in Lombardy, as shown in [34].

For each target day, its value and those of the six preceding days were used (7 values for calls + 7 values for ambulances dispatched = 14 attributes), and further elaborated to extract the following features from both signals:

- 'Position' features: max value, min value, max-min, time position of the max, and min values in the seven days (5 × 2 = 10 attributes);
- 'Statistical' features: mean value, median value, standard deviation (3 × 2 = 6 attributes);
- Linear regression features: intercept, slope, and Pearson's correlation coefficient of the linear regression (3 × 2 = 6 attributes);
- Exponential regression features: base numerical coefficient, exponential coefficient, and Pearson's correlation coefficient of the exponential regression (3 × 2 = 6 attributes).

The resulting total number of computed features was 42, and a detailed list is provided in Appendix A.

The following step (III) consisted of defining the ML classification algorithm to be trained and consequently applied to classify as '0' or '1' (i.e., 'no diffusion or 'active spreading', respectively) the current target day, based on a retrospective series of 7 data points for each territorial cluster, capturing the possible trends existing in such data, and the relevant label assignment probability. Following a trial-and-evaluation strategy, three different ML approaches (logistic regression, random forest classifier, and support vector machine, widely applied algorithms in the recent literature in the field of EMS demand forecast [48–50]), together with different combinations of their explicative attributes, were tested and optimized. Therefore, attribute selection was based on a trial-and-evaluation strategy rather than a priori techniques. The pre-processing of attributes consisted of a single step (the computation of derived attributes), and no further mathematical processing (such as Principal Components Analysis) was implemented.

A performance test was carried out using a 10-fold cross-validation protocol. The whole dataset was balanced in terms of validation labels, with both labels equally represented in terms of the number of records for each district and for each fold in the cross-validation process, thus guaranteeing a balance in both the test and the training set for all iterations; in addition, the order of the records was randomized to avoid feeding the algorithm with almost-periodical cycles.

With the most performant model identified, a further analysis was performed considering the probability of label assignment by the algorithm as a test threshold, thus inferring the area under the curve (AUC) of the receiving operator characteristic (ROC) curves. This analysis was conducted separately for the three main waves of COVID-19 occurring in Lombardy during the whole period under observation (as can be noticed from the example reported in Figure 1):

- The first wave, in the spring of 2020, with the original strain and no vaccine available.
- A second wave, from the autumn of 2020 to the spring of 2021, composed of two peaks, the former relevant to the Alpha variant (when vaccinations were not available yet) and the latter to the Delta variant (when vaccinations were available, with an increasing amount of vaccinated people over time).
- A third wave from the winter of 2021–2022 to the spring of 2022, relevant to the first Omicron variant, despite the high level of vaccination across the population.

To do so, the intervals corresponding to the different waves were computed separately for each district, setting the end of each wave 15 days after the identified ending inflection point. Data from each wave were evaluated as an external dataset, hence excluding them from the training phase, in order to avoid overfitting the model. From these curves, an optimal working point was identified through the index of union [51], allowing us to define an optimized sensitivity and specificity.

2.2. Model Post-Processing

Due to the simple and poorly informative binary classification, considering the large variability in the data, and the lack of an actual ground truth to validate the model, the output was further post-processed to be interpreted from a probabilistic perspective (step IV). Specifically, the probabilities associated with the label assignments relevant to four consecutive target days were considered, computing their mean value and mean daily

variation between consecutive days, and used separately to define two new features, each characterized by three possible labels:

- Confidence level: certainly low (mean value < 0.4), uncertain (mean value between 0.4 and 0.6), certainly high (mean value > 0.6);
- Confidence trend: decreasing (mean variation < −0.1), stable (mean variation between −0.1 and 0.1), increasing (mean variation > 0.1); the +/−0.1 threshold was selected as corresponding to the change in value necessary to move from a fully uncertain confidence level (0.5) to either low or high.

The thresholds for the confidence level were arbitrarily selected, but the reasoning behind this choice was to keep a balance between the post-processing and the original ML output: as a consequence, an uncertainty interval around the original 0.5 threshold was introduced, thus leading to the selected 0.4–0.6 range. The confidence trend thresholds followed consequently.

According to these two features, five 'alert classes' were defined as:

- Class 1: certainly low confidence level with a decreasing or stable confidence trend;
- Class 2: certainly low confidence level with an increasing confidence trend, or an uncertain confidence level with a decreasing confidence trend;
- Class 3: uncertain confidence level with a stable confidence trend;
- Class 4: uncertain confidence level with an increasing confidence trend, or a certainly high confidence level with a decreasing confidence trend;
- Class 5: certainly high confidence level with a stable or increasing confidence trend.

The number of classes was set to five in order to keep it minimal, targeting the best possible explicability while still accounting for both confidence level and confidence trend. A graphical representation of this post-processing is reported in Figure 2.

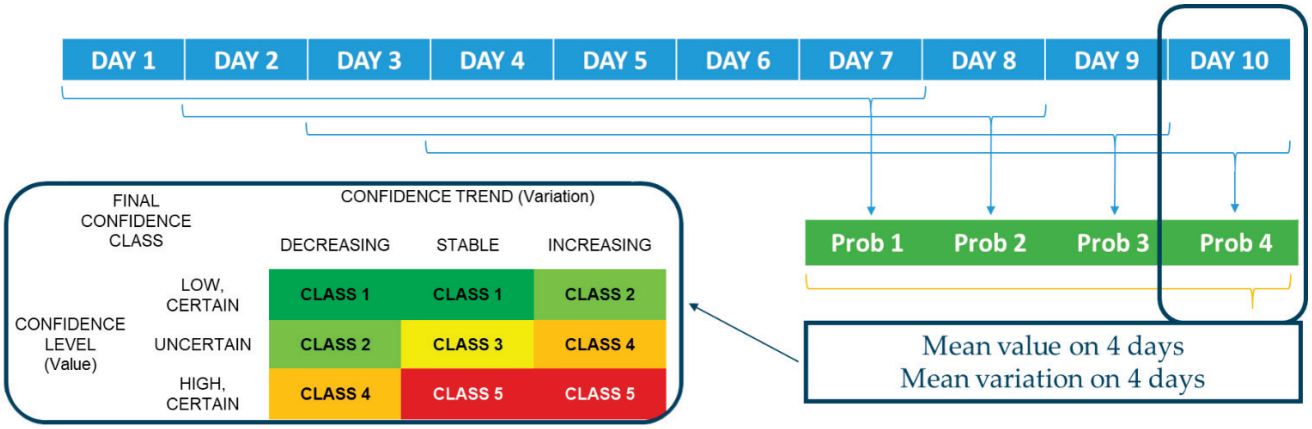

Figure 2. Post-processing elaboration of a machine learning model probability output, applied to classify the time series of ambulances dispatched and calls received by EMS for respiratory and infective issues (see text for details), to distinguish between a scenario of no epidemic diffusion and a scenario of active spreading by generating five possible classes of alert.

2.3. Geographical Processing

In order to avoid edge effects and to enhance real-world applicability by considering administrative boundaries, while the model was trained on the same geographical subdivision used in [34], it was instead applied at the level of each single municipality. To do so, it was necessary to compute 'dynamic' districts large enough to be statistically meaningful but centered on each single municipality. The first step was to compute driving-time distances among all municipalities, in order to perform an aggregation that could be more representative of a real-world scenario. Specific processing was applied to the city of Milan, which was subdivided into its 9 administrative sub-municipalities. The whole process resulted in a total number of 1514 municipalities in the Lombardy region, for which a 1514 × 1514 driving-time distance matrix was computed. A target of 100,000 residents was

set, where a population's municipalities except the target one (i.e., the center of the district) were weighted according to their distance (with distances scaled in the 0–1 range, and therefore applied as a weight): consequently, the overall absolute population of 'dynamic' districts actually resulted higher than 100,000. As a result, the 'dynamic' district, centered on a target municipality $\overline{m}$, was obtained by aggregating the closest $c = 1 \dots N$ municipalities, with priority given by the driving-time distance $d_{\overline{m}c}$ (scaled between 0 and 1 on the series of all $d_{\overline{m}c}$ with $c = 1 \dots 1513$) until the weighted total population wtp reached 100,000, with wtp computed as:

$$wtp = p_{\overline{m}} + \sum_1^N p_c \times d_{\overline{m}c}|_{0-1} \quad (1)$$

where $p_{\overline{m}}$ is the resident population in the target (center) municipality $\overline{m}$, p_c is the population of municipality c, and $d_{\overline{m}c}|_{0-1}$ is the driving-time distance between municipality $\overline{m}$ and municipality c (scaled between 0 and 1 in the entire region).

In order to focus on the target municipality, it was also necessary to differently weight the events (i.e., the dispatch of an ambulance or a call received by the EMS department for respiratory and infective issues) occurring in the 'dynamic' district. To this aim, the previously described weighting system was applied, based on the driving-time distance between the municipality where the event occurred (c_e) and the target municipality $\overline{m}$, thus computing a time series (for each day i) of events as:

$$TS_i = \sum_1^{E_{\overline{m}}} \frac{1}{wtp} + \sum_1^E \frac{1 \times d_{\overline{m}c_e}|_{0-1}}{wtp} \quad (2)$$

with:

$E_{\overline{m}}$ = total number of events during day i in the target municipality $\overline{m}$;

E = total number of events during day i in all the other municipalities within the 'dynamic' district;

$d_{\overline{m}c_e}|_{0-1}$ = drive-time distance (scaled between 0 and 1) between the municipality where the event occurred, c_e, and the target municipality $\overline{m}$.

3. Results

3.1. Model Development and Optimization

The optimization of the ML algorithm was performed on the basis of the results of the 10-fold cross-validation protocol, separately for each combination of explicative attributes and for each computational algorithm. Three different metrics (precision, recall, F1 score) were considered separately for each of the two labels (i.e., 'no diffusion' or 'active spreading') and also for all records together (with both flat and weighted averages), also adding the F1 score for accuracy. For all metrics, their distribution in the 10-fold cross-validation process (median, first quartile, third quartile, lower and upper 95% confidence interval) was considered, for a total of $3 \times 4 \times 5 + 1 \times 5 = 65$ parameters. However, these 65 parameters were weighted differently in order to give priority to the identification of true positives, thus resulting in a unique final score, representing the evaluation on which the classification decision was based. The different weights applied are reported in Table 2, and the complete results relevant to the final score obtained for each algorithm and tested attribute combinations are reported in Table 3.

According to this strategy, the model that resulted as the most performant was a random forest classifier fed with the 'position' and 'statistical' attributes of the two signals, yet without the time series, achieving an 81% F1 score (76% sensitivity, 87% specificity) for the 'no diffusion' label and a 79% F1 score (73% sensitivity, 85% specificity) for the 'active spreading' label, with a weighted overall score of 0.8052. Noticeably, the range of final scores reached by the different combinations is not wide and multiple combinations resulted in similar values (e.g., 10 combinations resulted in a weighted final score between 0.8 and 0.8052).

As regards the AUC evaluation for the three main waves of COVID-19, the results showed a good performance, with AUC values above 0.87 in the first and third wave, and a slightly lower value of 0.84 for the second wave, as can be expected considering that it was characterized by two distinct peaks and by an extended phase of plateau. The complete results are reported in Figure 3.

3.2. Model Post-Processing

As regards the significance of the classification process defined in the post-processing, there was no ground truth available to quantitatively validate its performance. However, it was hypothesized that the correct assignment to a certain class should be reflected by the difference in the number of ambulances dispatched by EMS in the following days. Therefore, this parameter was measured (considering the following 7 days) for all dynamic districts across the whole time series, and value distributions were computed for all five classes. This hypothesis was confirmed by a non-parametric Friedman test among all distributions, which resulted in a p-value < 0.001, followed by pairwise Wilcoxon's rank-sum tests (with Bonferroni correction) that showed p-values largely below 0.05. The complete results of these tests are reported in Table 4.

Table 2. Weights applied for the different metrics (precision, recall, F1 score), computed for the 'no diffusion' label, 'active spreading' label, and for the whole dataset, to evaluate the performance of a machine learning algorithm trained to identify these two scenarios, as resulting from a 10-fold cross-validation protocol; the median, first quartile, third quartile, and lower and upper 95% confidence interval values across the distribution among the 10 folds are reported (i.e., the median value of recall for the 'active spreading' label was weighted 0.1).

Weights Assigned to Different Parameters in the 10-Fold Cross-Validation		Precision	Recall	F1 Score
'No diffusion' label	Median	0.03	0.06	0.03
	1st quartile	0.0075	0.015	0.0075
	3rd quartile	0.0075	0.015	0.0075
	95% lower C.I.	0.0075	0.015	0.0075
	95% upper C.I.	0.0075	0.015	0.0075
'Active spreading' label	Median	0.05	0.1	0.05
	1st quartile	0.0125	0.025	0.0125
	3rd quartile	0.0125	0.025	0.0125
	95% lower C.I.	0.0125	0.025	0.0125
	95% upper C.I.	0.0125	0.025	0.0125
Accuracy	Median	NA	NA	0.06
	1st quartile			0.015
	3rd quartile			0.015
	95% lower C.I.			0.015
	95% upper C.I.			0.015
Macro Average	Median	0.015	0.03	0.015
	1st quartile	0.0038	0.0075	0.0038
	3rd quartile	0.0038	0.0075	0.0038
	95% lower C.I.	0.0038	0.0075	0.0038
	95% upper C.I.	0.0038	0.0075	0.0038
Weighted Average	Median	0.015	0.03	0.015
	1st quartile	0.0038	0.0075	0.0038
	3rd quartile	0.0038	0.0075	0.0038
	95% lower C.I.	0.0038	0.0075	0.0038
	95% upper C.I.	0.0038	0.0075	0.0038

Table 3. Optimization of a machine learning algorithm for a daily binary classification of territorial districts in the condition of the active spreading of the COVID-19 epidemic ('1') or no diffusion of the epidemic ('0') on the basis of ambulances dispatched and calls received by the EMS department in Lombardy, Italy, between 1 January 2020 and 13 March 2022. The table reports the final scores of different combinations of machine learning algorithms and attribute combinations (see Appendix A for a detailed list), computed by averaging the different metrics (and their distributions indicators) on the 10-fold cross-validation protocol, according to the defined weights (see Table 2). In bold, the highest results reached for each algorithm are highlighted, while the overall best result is also underlined.

Machine Learning Algorithm: Attributes Included *	Features Numbers (Ref. to Appendix A)	Random Forest	Support Vector Machine	Logistic Regression
All	1–42	0.7967	0.7809	0.7829
Time-Series (TS)	1–14	0.7887	0.7805	0.7818
All Derived Attributes	15–42	0.799	0.7804	0.7826
Ambulances Dispatches	1–7, 15–28	0.7965	0.7806	0.7827
Emergency Calls	8–14, 29–42	0.7939	0.7792	0.7811
Max-Min + TS	1–14, 15–19, 29–33	0.7934	0.7792	0.7819
Max-Min	15–19, 29–33	0.7981	0.7786	0.7798
Statistics + TS	1–14, 20–22, 34–36	0.7975	0.7787	0.78
Statistics	20–22, 34–36	0.8017	0.7791	0.7804
Position and Statistics + TS	1–14, 15–22, 29–36	0.8017	0.7791	0.7805
Position and Statistics	15–22, 29–36	**0.8052**	0.779	0.7806
Lin Regression + TS	1–14, 23–25, 37–39	0.8039	0.7789	0.7815
Lin Regression	23–25, 37–39	0.8032	0.7792	0.7815
Exp Regression + TS	1–14, 26–28, 40–42	0.8015	0.7597	0.7481
Exp Regression	26–28, 40–42	0.7996	0.7601	0.7482
Lin & Exp Regression	23–28, 37–42	0.7993	0.7604	0.7483
Position + Lin Reg + TS	1–19, 23–25, 29–33, 37–39	0.7983	0.7605	0.7484
Position + Lin Reg	15–19, 23–25, 29–33, 37–39	0.7994	0.7605	0.7484
Position + Exp Reg + TS	1–19, 26–33, 40–42	0.799	0.7605	0.7484
Position + Exp Reg	15–19, 26–33, 40–42	0.7996	0.7605	0.7483
Position + Lin & Exp Reg + TS	1–19, 23–33, 37–42	0.799	0.7606	0.7483
Position + Lin & Exp Reg	15–19, 23–33, 37–42	0.7991	0.7608	0.7484
Statistics + Lin Reg + TS	1–14, 20–25, 34–39	0.7883	0.7799	0.7837
Statistics + Lin Reg	20–25, 34–39	0.7974	**0.7815**	**0.7841**
Statistics + Exp Reg + TS	1–14, 20–22, 26–28, 34–36, 40–42	0.8005	0.761	0.749
Statistics + Exp Reg	20–22, 26–28, 34–36, 40–42	0.8009	0.7611	0.7489
Statistics + Lin & Exp Reg + TS	1–14, 20–28, 34–42	0.8002	0.7611	0.7501
Statistics + Lin & Exp Reg	20–28, 34–42	0.8003	0.7611	0.7503

* LEGEND (see Appendix A for detailed list): TS (time series) = daily calls to the EMS number, daily dispatches of EMS vehicles, relevant to respiratory and infective causes, normalized by the resident population; POSITION = max value, min value, max-min, position of the max and min values in the time window; STATISTICS = mean, median, standard deviation; LIN REG (Linear regression) intercept, slope, and Pearson's correlation; EXP REG (Exponential regression): base numerical coefficient, exp coefficient, and Pearson's correlation.

Within the GIS environment, it was possible to graphically represent the results of the model, thus enabling a powerful and quick visualization and interpretation of the data through mapping. Some examples are reported in the following Figure 4, relevant to the peaks of the three main waves (two different peaks were observed during the second wave) occurring in Lombardy during the analysis period.

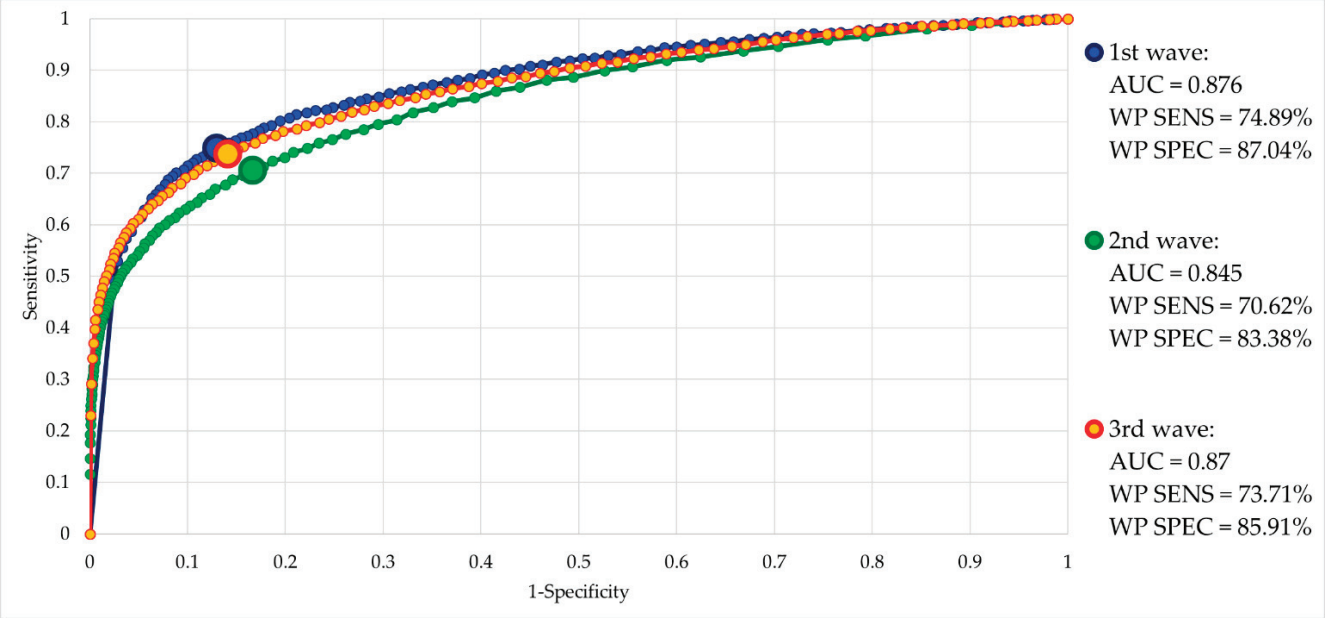

Figure 3. ROC curves representing the performance of the selected machine learning algorithm (random forest classifier) for a daily binary classification of territorial districts in the condition of the active spreading of the COVID-19 epidemic ('1') or no diffusion of the epidemic ('0') on the basis of ambulance dispatches and calls received by EMS department in Lombardy, Italy, between 1 January 2020 and 13 March 2022. The considered threshold is the label probability as provided in the output by the algorithm. The three COVID-19 waves (spring of 2020, autumn of 2020 to spring of 2021, winter of 2021–2022 to spring of 2022) were evaluated separately, training the model with the data from the other two. The area under the curve was computed, along with the sensitivity and specificity of their optimized [51] working points.

Table 4. Median (25th–75th percentile) of the number of ambulances dispatched for respiratory and infective issues by the EMS department on the territory of Lombardy, Italy, relevant to the 5 classes representing the level of confidence of being in a situation of the active spread of COVID-19, assigned by post-processing from the machine learning algorithm output for each municipality, between 1 January 2020 and 13 March 2022 (see text for details); the last column reports the *p*-values of pairwise Wilcoxon's rank-sum tests (after Bonferroni correction), assessing the difference in the distribution across different classes.

Assigned Class	Ambulances Dispatched/Population in the Following 7 Days: Median [25th–75th Percentile]	*p*-Value of Pairwise Wilcoxon's Rank-Sum Tests (Bonferroni Corrected)
Class 1	1.83 [0.96–2.55]	Class 2: $p < 0.001$ Class 3: $p < 0.001$ Class 4: $p < 0.001$ Class 5: $p < 0.001$
Class 2	3.21 [2.57–4.16]	Class 1: $p < 0.001$ Class 3: $p < 0.001$ Class 4: $p < 0.001$ Class 5: $p < 0.001$
Class 3	3.73 [2.85–4.69]	Class 1: $p < 0.001$ Class 2: $p < 0.001$ Class 4: $p < 0.001$ Class 5: $p < 0.001$

Table 4. *Cont.*

Assigned Class	Ambulances Dispatched/Population in the Following 7 Days: Median [25th–75th Percentile]	*p*-Value of Pairwise Wilcoxon's Rank-Sum Tests (Bonferroni Corrected)
Class 4	3.96 [3.00–5.03]	Class 1: $p < 0.001$ Class 2: $p < 0.001$ Class 3: $p < 0.001$ Class 5: $p < 0.001$
Class 5	6.24 [4.63–9.00]	Class 1: $p < 0.001$ Class 2: $p < 0.001$ Class 3: $p < 0.001$ Class 4: $p < 0.001$

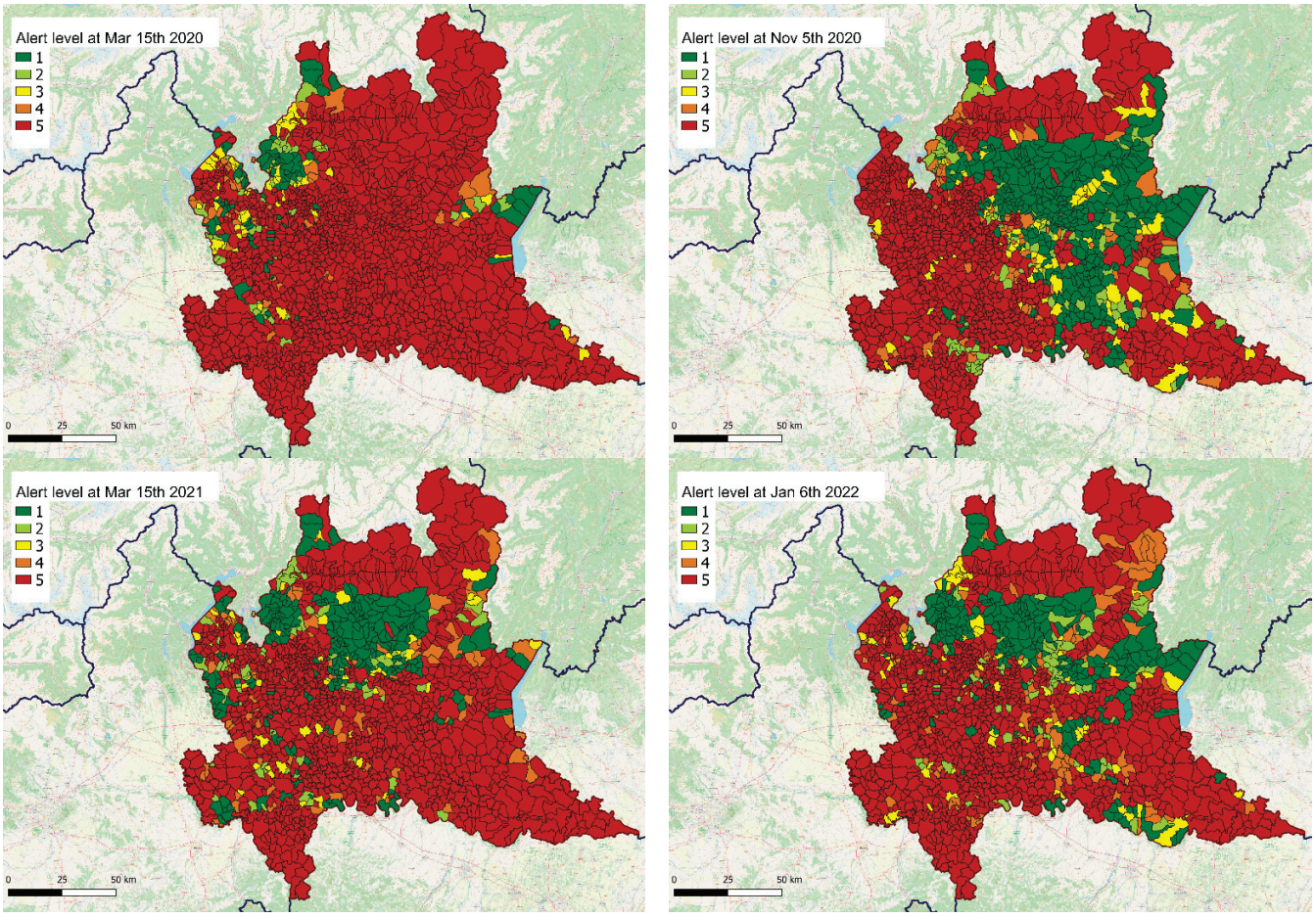

Figure 4. Map representation of the output of a machine learning model representing, for every municipality of Lombardy, Italy, the alert level of confidence, as expressed in five classes, of being in a condition of the active spreading of COVID-19, on the basis of a post-processing of the machine learning output. Four dates are here considered: 15 March 2020 (**top left**) as the peak of the first wave; 5 November 2020 (**top right**), as the first peak of the second wave; 15 March 2021 (**bottom left**), as the second peak of the second wave; and 6 January 2022 (**bottom right**) as the peak of the third wave.

4. Discussion

In this study, the development and validation of a monitoring model based on supervised learning (ML methods) for the evolution of COVID-19 was proposed, in order to make a step ahead from only descriptive analysis and thus generate an 'early-alert' system, with geographic granularity up to single municipalities. The choice of the best-performing algorithm and of the most informative set of attributes was carried out considering the

output of the spatial-temporal model presented in [34], and it is therefore based on the optimization of the accuracy in the binary classification. The best results were obtained with a random forest classifier, fed with the 'position' and 'statistical' attributes of the two signals, yet without the time series, reaching an overall accuracy of 80% (as computed with a 10-fold cross-validation protocol). Therefore, the first relevant result is represented by the higher performance achieved by the random forest classifier when compared with logistic regression and a support vector machine. A possible explanation could be related to the different nature of such ML algorithms: while logistic regression is a mathematical interpolation, and a support vector machine is a separation-based method, the random forest classifier is rule-based. As in our framework, the problem is posed as a classification task, rather than a numerical regression, it is not surprising that the best results are obtained using rule-based reasoning, especially as a consequence of the priority given to the identification of true positives (through the weighting system described in Table 2).

Similar considerations could be drawn for the optimization of the attributes set. The fact that the best results were obtained with 'position' and 'statistical' attributes can be interpreted as a consequence of the rule-based nature of the algorithm. The numerical series, together with their interpolations, are of low interest for the algorithm, which does not process them as signals but instead makes better use of their derived characteristics. Removing the time series from the input probably frees some computational capability (required to extract the relevant characteristic of the signal), which is redirected towards a better performance in the actual classification. The fact that the support vector machine and logistic regression were achieving better results when considering the linear regression on the signal, along with the statistical parameters, might confirm this hypothesis. It is worth noticing that the results are not largely different across the proposed algorithms, and are even closer across different attribute sets.

As the optimization process can still provide enhancements to the performance, it is not recommended to spend too much effort in this step, as the explainable and interpretable component of the phenomenon can be extracted quite easily, while the possibility of reaching a significantly higher performance is questionable. In this study, the focus was mainly put on the agility and replicability of the proposed framework. A possible increase in the performance, but at the expense of model explicability, could be achieved by exploring the application of different approaches, such as deep learning techniques, that could constitute the aim of future work.

Separate analyses were run on the three main COVID-19 waves that occurred in Lombardy, showing a higher performance on the first and third one, and slightly lower performance on the second wave, which, however, was characterized by a more complex profile, with two distinct peaks separated by a phase of plateau.

The need for research on the predictive capabilities of EMS calls in terms of hospitalizations, ICU demand, and casualties was encouraged in the recent literature [35], and multiple studies were, in fact, published about the use of EMS data in the monitoring and management of COVID-19 emergencies, such as:

- In October 2020, a study [36] was aimed at comparing trends of EMS data with the official data of COVID-19 cases and related casualties in the area of Tijuana, Mexico. The analysis was focused on two main targets: changes in out-of-hospital mortality, and a comparison of pre- and post-epidemic distributions of the values of oxygen saturation in hospitalized patients. The correspondence between the peaks of the analyzed indicators led the authors to the conclusion that EMS data are a valuable source to monitor excess out-of-hospital mortality due to COVID-19.
- In November 2020, a retrospective study [37] on the Ile-de-France region, France, was conducted, analyzing the correlation of six healthcare-related parameters, including the number of calls to EMS, with the demand for ICU beds, resulting in a significant time-dependent reproduction ratio with relevance to EMS calls, identifying it as a potentially useful predictor for monitoring and in organizational models to anticipate the demand for ICU beds.

- In February 2021, a study [38], further elaborating previous results [39] relevant to Kings County, WA (USA), correlated the number of COVID-19 diagnoses in a hospital setting with the identification of suspected patients, considering shortness of breath, cough, sore throat, muscle aches, loss of sense of smell or taste, or diarrhea. A significant correlation was identified, with a peak when considering in the model a nine-day lag period, suggesting that EMS data could anticipate the demand for hospital services, thus confirming the potentiality of such data in the planning of resource allocation and in the management of the healthcare system.
- A reverse perspective was recently proposed [40] in September 2021, to determine how the number of patients hospitalized for COVID-19 could help in foreseeing the demand for EMS, with reference to the Austin-Travis county (Texas, USA). The authors applied the 'change point detection' method to identify changes in the mean and variance of time series, subsequently studying with a *t*-test the distributions in the pre- and post-pandemic periods (as divided by the identified change point). On this basis, a regression model fed with forecasts of COVID-19 hospitalizations was developed and described as a successful method to predict the demand for EMS services, thus further confirming the correlation between these two measurements.

Compared to these state-of-art [36–40] studies, the main strength of the proposed model stands in combining a sound performance with a very high geographic granularity, which reached the level of single municipalities thanks to the proposed combination of ML and spatial filtering, a novel approach in the context of EMS data analysis. This enhancement could be extremely valuable in terms of applicability as support for decision-making, enabling policymakers to differentiate the interventions across the territory rather than managing uniformly the whole area of competence. A first immediate consequence could be hypothesized in the allocation strategy of emergency resources (mainly ambulances and related personnel), which can be optimized on the basis of a detailed demand analysis, thus avoiding a uniform distribution that could result in being under- or over-dimensioned at the same time in different areas, depending on the specific time-bounded needs for each territory.

Moreover, the model stands on minimum requirements in terms of data and processing capabilities. While it can be assumed that environmental, epidemiological, socio-economic, and demographic factors could improve the predictive capabilities of the model, the inclusion of such diverse data sources would pose severe barriers to its replicability and extendibility. By limiting the analysis to a single, widespread, and very simple data source, our model can be very easily implemented by other institutions in different territories.

Performing the validation of the model post-processing results, the main limitation that needed to be faced was the absence of an actual ground truth on which data could be validated, and on which the post-processing could be programmatically trained and calibrated. However, the meaningfulness of the proposed five classes could still be assessed, to some extent, by analyzing the number of vehicles dispatched by the EMS department for respiratory and infective issues in the seven following days, according to the alert class assigned. Indeed, the distributions of the values gave different results, with a progressively increasing number of ambulances dispatched according to the assigned model class, and those differences resulted as statistically significant (see Table 4), thus proving that the proposed strategy to define different alert classes was (at least to some extent) representative of different situations of the near-future evolution of COVID-19. The choice to focus the validation on the demand for EMS was enforced by the priority given to the early identification of an increase in the request for medical assistance, which is of higher concern compared to the bare increase in overall infections, including asymptomatic and mild cases.

From the presented results, some qualitative analysis can be drawn. First of all, the first wave (March–April 2020) appeared to be the worst, with a larger and more synchronous spreading across the territory. However, we cannot explain if this depended more on an effective wider diffusion of the disease, or rather on the management difficulties generated by an unprecedented, unexpected, and abrupt emergency, with a burden on

EMS departments beyond the maximal capabilities of the system [46,52]. The second wave (while the official numbers in terms of infections were almost ten times higher than in the first one) appeared close to the first but was less impactful, with a tighter maximal territorial diffusion. Interestingly, a specific geographic area was spared according to the model: it corresponds to a territory located in the provinces of Bergamo and Brescia, which were the most-affected worldwide areas during the first wave [46]. This result might therefore be explained as being due to a stronger natural immunization of the resident population, derived from the previous extreme diffusion of the disease, and to the reduced number of subjects at risk (due to the high mortality during the first peak). Similar considerations can be drawn for the second peak in the second wave, where again the spatial diffusion never covered the entire territory. The third wave appeared very similar to the second phase of the previous one, both qualitatively (in terms of geographic areas) and quantitatively (in terms of diffusion on the territory). It is noteworthy that, during the third wave, a five-fold increase in the daily infection cases with respect to the second one was officially recorded, and yet the impact on EMS was (as modeled in this study) somehow similar, showing how different the impact was on the healthcare system thanks to widespread vaccination. Since the summer of 2021, when vaccine coverage reached significant values in the area, the proposed model is probably more representative of the demand for medical care rather than of the actual diffusion of the disease—two different aspects previously intertwined but currently uncoupled. This characteristic may be valuable in the upcoming future, when it will be vital to suddenly detect any possible surge in the demand for EMS services due to either a new COVID-19 variant, a fall in vaccine-induced immunization, or a combination of these two factors.

5. Conclusions

In conclusion, the implementation of a data science approach to infer monitoring information relevant to the evolution of the COVID-19 pandemic, based on the georeferenced database of calls to the emergency number and ambulance dispatched for respiratory and infective issues by EMS, can be considered successful.

In particular, the novel geo-processing algorithm to build 'dynamic' weighted districts allowed the ability to reach a very high level of granularity (single municipalities), which is, to the extent of our knowledge, unprecedented for pandemic monitoring models. Compared to official data, the proposed model could be capable of anticipating the detection of new hotspots, thanks to the immediate usability of EMS data, which are (in most cases) automatically collected by EMS organizations and do not require additional structures for information flow (compared, for example, to the swab tests, which require processing, verification, and communication between different actors). Although a direct comparison with official data was not possible due to the absence of an actual ground truth, the proposed model could be considered less biased and more representative of the spread of the disease (at least before the availability of vaccines) and of the demand for medical care (also in the current scenario with a high share of population covered by vaccination).

In this consideration, the developed early alert model could show its high potential in detecting local abrupt surges in COVID-19 in the current situation (July 2022), where periodical recrudescence could be expected in the following months due to the lifting of protection rules and restrictions, in combination with a decline in the vaccine-induced immune response, as well as in the context of possible future pandemics representing unfortunate yet realistic scenarios we must cope with.

Author Contributions: Conceptualization: L.G. and E.G.C.; methodology: L.G., M.A.B. and E.G.C.; software: L.G.; validation: L.G.; formal analysis: L.G., M.A.B. and E.G.C.; investigation: A.P., G.D., R.B., P.M.B. and G.M.S.; resources: G.M.S. and E.G.C.; data curation: L.G., A.P., R.B. and G.M.S.; writing—original draft preparation: L.G. and E.G.C.; writing—review and editing: L.G., E.G.C., M.A.B., A.P., G.D., P.M.B., R.B., G.M.S.; visualization: L.G., M.A.B. and E.G.C.; supervision: M.A.B. and E.G.C.; project Administration: E.G.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: All data are available on reasonable request.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

A detailed description of the 42 features considered as input for the computational algorithm. The ambulances dispatched and calls to emergency number 112 are filtered for respiratory and infective issues only.

- Feature 1: Number of ambulances dispatched/100,000 residents at day $\bar{t} - 6$
- Feature 2: Number of ambulances dispatched/100,000 residents at day $\bar{t} - 5$
- Feature 3: Number of ambulances dispatched/100,000 residents at day $\bar{t} - 4$
- Feature 4: Number of ambulances dispatched/100,000 residents at day $\bar{t} - 3$
- Feature 5: Number of ambulances dispatched/100,000 residents at day $\bar{t} - 2$
- Feature 6: Number of ambulances dispatched/100,000 residents at day $\bar{t} - 1$
- Feature 7: Number of ambulances dispatched/100,000 residents at day $\bar{t}$
- Feature 8: Number of calls to emergency number 112/100,000 residents at day $\bar{t} - 6$
- Feature 9: Number of calls to emergency number 112/100,000 residents at day $\bar{t} - 5$
- Feature 10: Number of calls to emergency number 112/100,000 residents at day $\bar{t} - 4$
- Feature 11: Number of calls to emergency number 112/100,000 residents at day $\bar{t} - 3$
- Feature 12: Number of calls to emergency number 112/100,000 residents at day $\bar{t} - 2$
- Feature 13: Number of calls to emergency number 112/100,000 residents at day $\bar{t} - 1$
- Feature 14: Number of calls to emergency number 112/100,000 residents at day $\bar{t}$
- Feature 15: Min value of ambulances dispatched/100,000 residents (min in features 1 to 7)
- Feature 16: Max value of ambulances dispatched/100,000 residents (max in features 1 to 7)
- Feature 17: position of the min value of ambulances dispatches (feature 15) in the time window (from 1 to 7)
- Feature 18: position of the max value of ambulances dispatches (feature 16) in the time window (from 1 to 7)
- Feature 19: difference between max and min value of ambulances dispatched
- Feature 20: standard deviation of the distribution of ambulances dispatched in the time window (feature 1 to 7)
- Feature 21: mean of the distribution of ambulances dispatched in the time window (feature 1 to 7)
- Feature 22: median of the distribution of ambulances dispatched in the time window (feature 1 to 7)
- Feature 23: intercept of the linear regression on ambulances dispatched in the time window (q in $y = q + cx$)
- Feature 24: slope of the linear regression on ambulances dispatched in the time window (c in $y = q + cx$)
- Feature 25: Pearson's correlation coefficient of the linear regression on ambulances dispatched
- Feature 26: base coefficient of the exponential interpolation on ambulances dispatched in the time window (b in $y = be^{ax}$)
- Feature 27: exponential coefficient of the exponential interpolation on ambulances dispatched in the time window (a in $y = be^{ax}$)
- Feature 28: Pearson's correlation coefficient of the exponential interpolation on ambulances dispatched
- Feature 29: Min value of emergency calls/100,000 residents (min in features 8 to 14)

- Feature 30: Max value of emergency calls/100,000 residents (max in features 8 to 14)
- Feature 31: position of the min value of emergency calls (feature 29) in the time window (from 1 to 7)
- Feature 32: position of the max value of emergency calls (feature 30) in the time window (from 1 to 7)
- Feature 33: difference between max and min value of emergency calls
- Feature 34: standard deviation of the distribution of emergency calls in the time window (feature 8 to 14)
- Feature 35: mean of the distribution of emergency calls in the time window (feature 8 to 14)
- Feature 36: median of the distribution of emergency calls in the time window (feature 8 to 14)
- Feature 37: intercept of the linear regression on emergency calls in the time window (q in $y = q + cx$)
- Feature 38: slope of the linear regression on emergency calls in the time window (c in $y = q + cx$)
- Feature 39: Pearson's correlation coefficient of the linear regression on emergency calls
- Feature 40: base coefficient of the exponential interpolation on emergency calls in the time window (b in $y = be^{ax}$)
- Feature 41: exponential coefficient of the exponential interpolation on emergency calls in the time window (a in $y = be^{ax}$)
- Feature 42: Pearson's correlation coefficient of the exponential interpolation on emergency calls

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International Journal of
Environmental Research and Public Health

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Objective and Subjective Stress Parameters in Response to High and Low-Fidelity Simulation Activities

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Citation: Czekirda, M.; Misztal-Okońska, P.; Włoszczak-Szubzda, A.; Goniewicz, M.; Cybulski, M.; Kowalczuk, K.; Jaszyna, N.; Pyć, M.; Gnat, M.; Girzelska, J.; et al. Objective and Subjective Stress Parameters in Response to High and Low-Fidelity Simulation Activities. *Int. J. Environ. Res. Public Health* **2022**, *19*, 2980. https://doi.org/10.3390/ijerph19052980

Academic Editor: Paul B. Tchounwou

Received: 16 January 2022
Accepted: 1 March 2022
Published: 3 March 2022

Abstract: Nursing graduates are required to have both excellent theoretical and practical skills that should be used during stressful emergency interventions. Since the received knowledge should be practiced to gain skills and trained to achieve competences, simulation exercises can be beneficial to even reduce the stress that each individual may face during emergency management of patients. A total of 146 first-year nursing students participated in the study, including 124 women and 22 men aged between 19 and 50 years, with a mean age of 32 years. The objective method estimated psychophysiological parameters (serum cortisol). Objective and subjective methods were used. The subjective method assessed stress experienced by students based on the standardized Stress Appraisal Questionnaire Version B for dispositional assessment. The study was conducted in the Monoprofile Medical Simulation Centre at the University of Economics and Innovation in Lublin, Poland and was approved by the University Research Ethics Committee. Both participants under and over 25 years of age showed increased levels of stress after low and high-fidelity simulations, with statistically significantly higher stress levels found for the low fidelity method. Low-fidelity simulation methods generated a greater increase in cortisol levels, indicating a higher stress level than the high-fidelity methods. The analysis of the scores obtained in the Stress Appraisal Questionnaire (KOS-B) showed that higher cortisol levels after the low-fidelity simulation reduced the subjective perception of a threat, while higher cortisol levels before the high-fidelity simulation promoted higher intellectual activity among the students. Levels of stress in the education of nursing students using low and high-fidelity methods can limit the sense of threat and activate professional task performance. The use of low and high-fidelity simulation does not generate destructive stress levels.

Keywords: stress; stressors; cortisol; medical simulation; low-fidelity simulation; high-fidelity simulation; stress appraisal questionnaire; KOS-B; education; nursing

1. Introduction

The use of modern technologies has become a standard in the educational process. In the case of medical universities, this approach guarantees the development of skills, competences and professionalism in students. A special role is played by simulation-based education, which offers the possibility to recreate potential clinical cases to enable students gain experience and learn about medical procedures in a safe environment [1]. Simulators give students the opportunity to intervene and evaluate treatment and care outcomes [2]. Simulators, models and phantoms allow for the acquisition and consolidation of technical skills related to manual procedures, e.g., cardiopulmonary resuscitation, catheterization, intubation, insertion of an infusion [3]. There are many scientific reports confirming that simulation is an effective educational tool in the field of medicine, including nursing [3–9].

Fidelity simulation is multidimensional. The degree of realism is reflected through a detailed scenario, scenery and the selection of simulation equipment. Fidelity is also defined by the degree of accuracy and reliability of the experience. It can be low, medium, and high, and its types are physical, psychological, and conceptual. The level of fidelity should be conducive to achieving the expected educational results [10].

Low Fidelity Simulation (LFS) is performed using partial trainers i.e., mannequins or equipment representing certain anatomical parts of the human body. These are crucial instruments for learning essential nursing skills such as intramuscular or intravenous injections, inserting a peripheral IV catheter, etc. [11]. The level of fidelity should be also appropriate to the type of task and training stage. At more advanced levels of training, the level of fidelity should support higher levels of speed and practice of task [12]. The appropriate level of fidelity is dependent on the intended learning goals and cost. Different levels of fidelity may be needed for different objectives and levels of trainees [12].

High Fidelity Simulation (HFS) allows for maximum experiential learning, using phantoms with multiple complex functions that realistically reflect the vital functions of the human body. The advanced interactive capabilities of the phantoms enable students to act in real-life scenarios. Students are able to detect and correct errors themselves without negative consequences for the patient. In this way they acquire both clinical skills and social competences without a fear in a safe environment with no stress. High-fidelity simulation is performed in simulated intensive care rooms, delivery rooms, operating rooms, and even hospital emergency departments [13,14]. High-fidelity simulation has been shown to support soft skills and task-focusing, enhance the sense of self-competence, develop self-confidence, self-efficacy, sense of satisfaction, as well as clinical thinking, skills, judgment, and decision-making [11,13,15]. It also provides a safe and developmental practice space to gain experience in situations that are likely to be encountered in the future professional work [16]. The possibility to perform procedures repeatedly during practice is an excellent way to control psychological states and experiences such as uncertainty, apprehension, and anxiety that accompany the nursing profession, especially at the beginning of a career [17–20].

Previous research shows that fidelity simulation training is very popular with students and is received with enthusiasm [21–24]. Furthermore, many studies indicate that simulation based on scenarios played out by the students themselves improves teamwork skills [25–27].

The effectiveness of high and low-fidelity methods in the nursing education process is currently beyond question. However, there is little research that explains whether these techniques, regardless of their benefits, are also a source of stress, as in the real emergency encounter, how students cope with such situations and if this stress is beneficial. The novelty of our proposed research lies in focusing on objective indicators of stress experienced by students during high and low-fidelity simulation activities based on cortisol levels. We compared this indicator with the students' subjective estimate of stress levels during the activities.

2. Aim of the Study

The aim of the study was to assess the differences in the level of stress assessed objectively (cortisol level) and subjectively (Stress Assessment Questionnaire, KOS-B), under simulation conditions using low and high-fidelity education methods.

3. Materials and Methods

3.1. Study Material

The study involved 146 students (124 females, 22 males) aged 19–50 years (M = 31.83, MD = 31.00, *SD* = 7.76) from the University of Economics and Innovation in Lublin, Poland, most of whom were professionally active (83.6%): 25 (17.1%) paramedics, 34 (23.3%) healthcare assistants, 11 (7.5%) physiotherapists, and 52 (35.6%) other healthcare professions. Secondary and higher education was reported by 83 and 63 respondents ($\chi^2 = 2.740$, $p = 0.098$), respectively. Detailed demographic characteristics of the study group are presented in Table 1.

Table 1. Demographic characteristics of the study group.

			Age				Education				Place of Residence			
							Secondary		Higher		R	U < 100	U > 100	SU
	N	%	Min–Max	M	MD	*SD*	N	%	N	%	%	%	%	%
total	146	100	19–50	31.83	31.00	7.76	83	56.8	63	43.2	47.9	28.1	21.9	2.1
women	124	84.9	19–50	32.27	32	7.96	71	57.3	53	42.7				
men	22	15.1	20–42	29.63	28.50	6.09	12	54.5	10	45.5				

R—rural; U—urban, SU—suburban.

3.2. Research Methods

The study used two research methods (a) laboratory analysis of serum cortisol levels and (b) questionnaire assessment of perceived stress (Stress Appraisal Questionnaire Version B).

Analysis of serum cortisol level: Serum cortisol was measured to objectively assess the level of stress experienced by the students. Activation of the hypothalamic-pituitary-adrenal axis in response to stressful stimuli triggers increased production of glucocorticoids to restore homeostasis. Cortisol is the main glucocorticoid hormone produced by the adrenal cortex. Its increased amounts are released in response to high levels of stress to mobilize the body's resources. Among others, cortisol raises blood glucose levels, has immunosuppressive and anti-inflammatory effects, and is responsible for salt retention in the body. Chronically elevated cortisol may have adverse consequences for health [28,29].

3.3. Preparation for Blood Collection

A week before the scheduled blood collection, the students were informed how to prepare for the test. In order to obtain reliable serum cortisol measures, the students were asked to follow the following recommendations:

- avoid stressful situations a few days before sampling, if possible;
- avoid alcohol for 3 days before the analysis;
- report fasted for the test (12 h after the last meal);
- drink a glass of water a few minutes before the test;
- rest for at least 30 min before sampling.

Pregnant women and estrogen-treated women were excluded from the study due to elevated cortisol levels in both these groups.

3.4. Next Phase

The study was implemented in two stages.

- The first stage took place in December 2019 among students participating in nursing skills classes implemented in the first semester using a low-fidelity method before and

after parameter measurements. Cortisol was measured in the blood sampled before and after completing measurements.

- The same procedure as in the first stage of the study was performed, i.e., blood collection took place before and after passing the parameter measurement using the high-fidelity method.

Samples were collected in the morning (between 8:00 and 10:00 a.m.) in seven groups of students and in the afternoon (between 5:00 and 6:15 p.m.) in eight groups of students. The students in each group had their blood sample taken at the same time each time (both in the first and second stage of the study), i.e., during the classes of their study group. At each stage, the students also completed The Stress Appraisal Questionnaire.

3.5. Laboratory Analysis—Serum Cortisol Levels

Blood was collected twice, before and after low and high-fidelity simulation sessions. A vacuum-venipuncture technique was used (by nurses) to collect blood. The tubes and referrals for the test were then coded. The blood collected from the students was centrifuged by a laboratory staff for 10 min at 3500 rpm. The obtained serum was taken to the laboratory, where it was stored at −80 °C and then analyzed.

The Alinity and Cortisol kit is a Chemiluminescent Microparticle Immunoassay (CMIA) for the quantitative determination of cortisol in human serum, plasma or urine using the Alinity analyzer. In healthy individuals, cortisol levels are regulated by a negative feedback loop in which the adrenal cortex responds to elevated adrenocorticotropic hormone (ACTH) through increasing cortisol secretion, and the pituitary gland responds to elevated cortisol by decreasing ACTH production. Plasma cortisol levels peak in the morning and decrease by about half in the evening. The analysis of the biological material was performed on the ARCHITECT i System analyzer. The results obtained in individual laboratories may differ from these data as each laboratory has its own reference range specific for a given latitude and population (we use: Laboratory of Medical Analyzes ALAB Lublin Ceramiczna ul. Ceramiczna 20-150 Lublin, Poland).

3.6. Reference Range for Serum Cortisol

Serum cortisol values were obtained from samples taken from adults (considered healthy) before 10:00 a.m. and after 5:00 p.m. A 95% reference range was determined for the study group in which samples were collected before and after noon. The obtained results are summarized in Table 2 below.

Table 2. Reference range for serum cortisol in the laboratory where the study material was analyzed.

			95% Reference Range	
Type of Sample	**Sampling**	**n**	**μg/dL**	**Nmol/dL**
serum	Before 10 a.m.	150	3.7–19.4	102.1–535.2
serum	After 5:00 p.m.	150	2.9–17.3	80.0–477.3

The objective stress assessment based on cortisol levels was performed in parallel with the subjective assessment. For this purpose, each participant was asked to complete the Stress Appraisal Questionnaire (version B). The timing of the questionnaire was in coordination with the objective assessment, i.e., before and after completing the measurements of low and high-fidelity parameters in MMSC.

3.7. Description of the Research Tool—KOS-B

The Stress Appraisal Questionnaire (KOS) [30] allows for the diagnosis of the type and severity of stress experienced by respondents in stressful situations. The theoretical background for the tool is the transactional model of stress and coping developed by Lazarus and Folkman [31] and the interactional model of coping based on this theory (with amendments by Wrześniewski [30]). The tool measures the appraisal of currently

experienced stressful situation ('situational stress appraisal'—KOS-A) and the related personality dispositions ('dispositional stress appraisal'—KOS-B). The present study used the KOS-B version, which measures stress intensity in four subscales: threat—nine diagnostic items, harm/loss—four items, challenge-activity—five items, challenge-passivity—five items. The remaining statements have a buffering function. The higher the score in a given subscale, the higher the level of appraisal of a given stressful situation. The respondents are asked about how they generally perceive different stressful situations. In both parts, the responses are rated on a scale of 0 to 3, where: 0 = definitely not; 1 = rather not; 2 = rather yes, 3 = definitely yes. In practice, each part can be used separately. Completing one of the KOS parts takes about 10 min. The accuracy of the tool was determined based on factor validity and criterion (diagnostic) validity of selected subscales based on the analysis of KOS correlation coefficients with other measures of psychological properties. The reliability of the questionnaire was determined using the following methods: α-Cronbach's internal consistency and the Guttman Split-half coefficient.

The reliability parameters of the questionnaire are satisfactory and reach the following values for the individual factors: for the situational assessment, the α-Cronbach's for Threat = 0.90, Harm/Loss = 0.80, Challenge-activity = 0.71, Challenge-passivity = 0.76. For the dispositional appraisal, the reliability coefficient values are as follows: α-Cronbach's for Threat = 0.90, Harm/Loss = 0.84, Challenge-activity = 0.81, Challenge-passivity = 0.79 [30].

3.8. Ethics

The study was conducted at the turn of 2019 and 2020 at the Monoprofile Medical Simulation Centre (MMSC). The participants were informed of the purpose of the study, as well as the possibility of withdrawing at any time and without giving any reason. All participants gave their informed and voluntary consent to participate in the study. The approval of the Bioethics Committee for Ethics operating at the Higher School of Economics and Innovation in Lublin was obtained prior to the start of the study (application No. 2019/12/1, dated 19 December 2019).

3.9. Statistical Analysis

Statistical analysis was performed using SPSS Statistics version 25. A level of $\alpha < 0.05$ was considered statistically significant. Descriptive statistics were used to describe the variables: mean, median, standard deviation, kurtosis. Shapiro–Wilk and Kolmogorov–Smirnov tests were used to evaluate the distribution of variables. For variables significantly deviating from the normal distributions, an attempt was made to normalize by the natural logarithm. For the variables that met the assumptions for the parametric tests (measurement of cortisol after normalization), a *t*-test was used for repeated measurements. For the variables that did not meet the assumptions (KOS results) for the parametric tests, the non-parametric tests of the Wilcoxon signs test were used. Correlation tests were used to assess the dependence of quantitative variables—the Rho Spearman correlation coefficient.

4. Results

The Kolmogorov–Smirnov analysis of the distribution of results (for N > 100) showed that they mostly deviated from a normal distribution. Only in two cortisol measurements performed after the low-fidelity and high-fidelity simulation sessions, the distributions of the results were close to a normal distribution (Table 3).

The analysis of the mean stress scores obtained in KOS has shown the only change in the case of the general dimension ($M\_KOS_{\_GL\_before}$ = 22.22, SD = 6.07; $M_{\_KOS\_GL\_after}$ = 26.38, SD = 6.90). The mean values of the four questionnaire dimensions (threat, challenge-activity, challenge-passivity, and harm) were found to be identical before and after simulation sessions.

Table 3. Descriptive statistics of study variables.

	M	MD	*SD*	Skewness	Kurtosis	λ	*p*
KOS_GEN_before	22.22	21.00	6.07	0.113	0.824	0.107	<0.001
KOS_GEN_after	26.38	28.00	6.90	−0.513	−0.148	0.104	<0.001
KOS_THREAT_before	3.29	3.00	3.18	1.364	1.443	0.214	<0.001
KOS_THREAT_after	3.29	3.00	3.18	1.364	1.443	0.214	<0.001
KOS_CHAL_ACT_before	8.23	8.00	2.35	−0.025	0.674	0.104	<0.001
KOS_CHAL_ACT_after	8.23	8.00	2.35	−0.025	0.674	0.104	<0.001
KOS_CHAL_PAS_before	9.47	9.00	2.65	−0.126	0.789	0.087	0.002
KOS_CHAL_PAS_after	9.47	9.00	2.65	−0.126	0.789	0.097	0.002
KOS_HARM/LOSS_before	1.23	1.00	1.46	1.321	1.342	0.228	<0.001
KOS_HARM/LOSS_after	1.23	1.00	1.46	1.321	1.342	0.228	<0.001
Cortisol_1_before	90.53	82.00	39.12	1.186	1.701	0.132	<0.001
Cortisol_1_after	116.80	112.5	42.19	1.304	2.286	0.062	0.200 *
Cortisol_2_before	112.75	106.00	42.44	1.008	1.803	0.106	<0.001
Cortisol_2_after	117.57	121.50	44.80	0.292	0.180	0.051	0.200 *

KOS_GEN—KOS general; KOS_THREAT—KOS threat; KOS_CHAL_ACT—KOS challenge activities; KOS_CHAL_PAS—KOS challenge passive; KOS_HARM/LOSS—KOS harm/loss; *—statistical significance.

Psychological stress assessment based on blood sampling before the low-fidelity simulation showed that the mean cortisol level was $M_{\_1\_before}$ = 90.53, with standard deviation *SD* = 39.12. After simulation, there was a statistically significant increase ($p < 0.001$) in cortisol levels to $M_{\_1\_after}$ = 116.80, *SD* = 42.19. The difference in the means was 26.27.

Stress assessment based on blood sampling before the high-fidelity simulation showed that the mean cortisol level was $M_{\_2\_before}$ = 112.75, with a standard deviation of *SD* = 42.44. After the high-fidelity simulation, there was an increase in cortisol level to $M_{\_2\_after}$ = 117.57, *SD* = 44.80, with the difference in the means of 4.82, which did not meet the criterion of statistical significance, but remained at the trend level ($p = 0.093$), (data Table 3).

The indicators were important obtained of the level of experienced stress (blood sampling before and after low-fidelity simulation) F(1,145) = 173.170, $p < 0.001$, η2 = 0.544, the observed power of the test was 1.00. The difference in means was significant for cortisol levels (M_1_CORT_before − M_1_CORT_after = −26.27, *SD* = 24.12, t(145) = 13.159, $p < 0.001$). A negative result indicates increased cortisol levels in blood sampling "after low-fidelity the simulation". Thus, the level of stress experienced was higher after a low-fidelity simulation session and this result was found to be consistent with the students' subjective experience of stress (KOS low-fidelity simulation).

For the blood collection, before and after high-fidelity simulation, the difference in the means remained at a trend level (M_2_CORT_before − M_2_CORT_after = −4.82, *SD* = 34.46, t(145) = −1.691, F(1,145) =2.858, η2 = 0.019, $p = 0.093$, with the test power of 0.390).

Thus, it appears that low-fidelity simulation gave rise to higher physiological and subjectively perceived stress than high-fidelity sessions. The level of experienced stress, (criterion cortisol) and subjectively (KOS) perceived stress was higher after low-fidelity simulation sessions. For the high-fidelity simulation, the difference in the level of experienced stress (measure: cortisol and KOS) appeared to remain at the trend level.

The result calculated with $\alpha = 0.05$ revealed a significant main effect for subjective stress appraisal, measured based on the total pre- and post-simulation KOS score F(1,145) = 25.548, $p < 0.001$, η2 = 0.150, with the observed power of the test of 0.999. The difference in the mean stress appraisal scores between the measurements 1 and 2 (before and after collection) proved to be significant ($M_{\_I\_KOS} - M_{\_II\_KOS}$ = −4.16, *SD* = 9.95, t(145) = −5.055, $p < 0.001$).

There was a very weak statistically significant negative correlation between the sense of threat and cortisol levels after low-fidelity simulation sessions ($r = -0.194$). This indicates that higher cortisol levels after a session reduce the sense of threat (Table 4).

Table 4. Self-reported dispositional stress of respondents before and after low-fidelity simulation sessions.

		Threat	Challenge Activity	Challenge Passivity	Harm/Loss
		Measurement 1	**Measurement 1**	**Measurement 1**	**Measurement 1**
cort. sampling 1 BEFORE	Spearman's rho	−0.153	0.014	−0.129	−0.117
	p	0.065	0.866	0.122	0.160
cort. sampling 1 AFTER.	Spearman's rho	−0.194 *	−0.006	−0.046	−0.079
	p	0.019 *	0.940	0.584	0.342
		Measurement 2	**Measurement 2**	**Measurement 2**	**Measurement 2**
cort. sampling 2 BEFORE	Spearman's rho	0.011	0.17 *	0.056	0.011
	p	0.895	0.039 *	0.502	0.900
cort. sampling 2 AFTER	Spearman's rho	−0.126	0.036	−0.001	0.017
	p	0.130	0.668	0.988	0.836

cort. sampling—cortisol sampling; 1 measurement—low-fidelity simulation; 2 measurement—high fidelity simulation. *—statistical significance.

For the high-fidelity method, a very weak statistically significant positive correlation was found between pre-simulation cortisol levels and the challenge-activity score ($r = 0.171$), indicating that higher cortisol levels promoted activity among the students (Table 4.).

Another analysis was performed to assess the experienced (cortisol measurement) and estimated stress (KOS score) taking into account demographic variables such as age, gender and place of residence. Detailed results of this analysis are presented in Table 5. Significant correlations were found only between age and cortisol measurement in a low-fidelity simulation setting. It was shown that the mean pre-simulation cortisol level in participants < 25 years of age was $M = 100.83$ ($SD = 34.11$). There was a statistically significant increase ($p < 0.000$) in cortisol levels to $M = 127.56$ ($SD = 34.61$) after a low-fidelity session. The mean pre-simulation cortisol level was $M = 87.16$ ($SD = 40.20$) in students $\geq$ 25 years of age. There was a statistically significant increase ($p < 0.000$) in cortisol levels to $M = 113.28$ ($SD = 43.96$) after a low-fidelity session also in this age group. For the high-fidelity method, no statistically significant differences were found in cortisol levels in younger and older participants.

In conclusion, both participants $\leq$ and >25 years of age showed increased levels of stress after low and high-fidelity simulation; however, statistically significantly higher stress levels were observed only for the low-fidelity method.

Table 5. The rho-Spearman correlation analysis between age and the experienced and perceived stress.

		Cortisol 1_before	Cortisol 1_after	Cortisol 2_before	Cortisol 2_after	KOS_G1	KOS_G2	KOS_D_1	KOS_D_2	KOS_C_A_1	KOS_C_A_2	KOS_C_P_1	KOS_C_P_2	KOS_H/L	KOS_H/L
age	rho	−0.212 *	−0.214 *	−0.149	−0.085	0.152	0.022	0.077	0.077	0.090	0.090	0.158	0.158	0.034	0.034
	p	0.010 *	0.010 *	0.073	0.305	0.067	0.795	0.354	0.354	0.279	0.279	0.057	0.057	0.680	0.680

KOS_D—KOS_danger; KOS_C_A—KOS_challenge_activity; KOS_C_P—KOS_challenge_pasivity; KOS_H/L—KOS_harm/loss, *—statistical significance.

5. Discussion

Humans are exposed to stress in all areas of their activity. Hans Selye was the first to propose the biological concept of stress [32]. He distinguished between the concepts of positive and negative stress. Distress (negative stress) is a state of deprivation or overload that leads to disorganization. Eustress (positive stress), on the other hand, leads to personality development despite temporary discomfort. In the light of recent reports, stress reactions are definitely considered as specific, i.e., dependent on the nature of the stressor and individual characteristics of a given person. The period of studies is undoubtedly associated with significant exposure to stress related to entering adulthood, becoming independent, and building new relationships. The first year of university is particularly stressful due to the accumulation of multiple stressors arising from separation from family, adjusting to college demands, and facing confrontation as a student [33–35].

It has repeatedly been shown that nursing students are particularly vulnerable to stress and anxiety reactions due to the nature of the faculty itself, the specificity of classes, multiple demands, and the complexity of expectations. These have a detrimental effect on the sense of control and self-efficacy, and these, after all, are particularly expected of these students upon completion of their education [34,36,37].

McGuire and Lorenz reviewed 2009–2016 publications to analyze data on the levels of stress experienced by medical students and practitioners during simulation and the impact of stress on performance [38]. Student stress levels in simulated conditions were also measured by cortisol levels. The authors often measured cortisol immediately before and immediately after the simulation. In all the studies reviewed, cortisol levels increased after simulation, providing strong evidence that simulation can induce stress. The authors' findings suggest that cortisol is an important measure of stress in simulation. Of the 17 publications meeting the criteria for inclusion in the review, findings from six articles indicated impaired performance when stress was elevated, with lower performance scores observed in groups of highly stressed students. However, the evidence is not conclusive as to whether elevated stress during simulation improves performance. In contrast, our results showed a very weak statistically significant positive correlation between pre-simulation cortisol levels and the challenge-activity score ($r = 0.171$) for the high-fidelity method, indicating that a slight increase in cortisol levels may contribute to student activity.

In contrast, Kang and Min conducted a qualitative study to verify students' perceptions of psychological safety in high-fidelity nursing simulation and standardized patient scenarios [39]. The results indicated that students experienced anxiety, concern, and even fear during and after the nursing simulation, emotions that go beyond the concept of anxiety. In this study, students reported that their increased stress levels largely resulted from the fact that the sessions were recorded by other students and then watched during debriefing. The awareness that their actions were being watched by the teacher and other students led to blockage, increased perceived anxiety, and could consequently lead to more mistakes being made [34]. Perhaps the groups of practicing students should be reduced, and the recording of the sessions should be discussed only in a small group of those directly involved in performing the simulation scenario, which will increase the sense of intimacy and thus reduce stress levels.

Significant psychological stress can impair the learning process and affect the physical and mental health of students [40] therefore, stress monitoring is needed to verify whether the stress experienced during classes is physiological and arises from the learning process or whether it is destructive. Systematic assessment of stress and anxiety among students will allow university staff to quickly identify the problem and take appropriate measures if necessary. Evidence suggests that stress among students can be reduced through various interventions [34].

Our study indicates that low-fidelity simulation induced more physiological and subjectively perceived stress than high-fidelity sessions. Low-fidelity sessions employed simple simulators, e.g., a vascular access trainer or BLS trainer torso, etc. The training on the simulators is usually done individually, with each student practicing on their own

and then passing the acquired practical skills. High-fidelity simulation, on the other hand, uses advanced mannequins with a number of functions that imitate the parameters of the human body. Learning with high-fidelity simulators is mostly scenario-based and performed by a team/group of students, usually after mastering basic nursing skills in a low-fidelity simulation setting [41]. Thus, students may feel more confident having already mastered the fundamental skills, having the support of their groupmates, and knowing that they share responsibility for the success or failure of the scenario they are playing out.

Spies and Botma showed that students should be thoroughly acquainted with simulation practice and know in advance what will be expected of them when participating in scenarios [42]. The authors suggest that the sessions should start with less complex scenarios before moving on to more complex ones, which will prevent cognitive overload. Additionally, they point out that failures should not be punished during the debriefing and discussion so that the students could get more engaged and motivated to perform better in subsequent simulation training sessions [42].

In the context of stress, it is impossible to ignore the alarming statistics that show a systematic increase in mental disorders and emotional difficulties among students. Norwegian research has shown that the percentage of students with mental disorders doubled (from 16% to 29%) between 2010 and 2018. This is accompanied by loneliness in 20% of students [43].

It is difficult to compare the analysis of self-reported dispositional stress measured with KOS-B before and after low and high-fidelity simulation sessions with similar studies due to the lack of analogous empirical literature reports. However, our study sheds some light on the issue of university staff education. University teachers working with students in a simulation setting should be properly trained in conducting this type of classes [44–46]. This includes the ability to develop scenarios that consider the outcomes of learning, observation, and appropriate responses. Lecturers become trainers and instructors of simulation, which requires them to conduct sessions in such a way that they do not cause destructive stress or negative emotions.

Our study has shown that participation in low and high-fidelity simulation training induces physiological stress reactions that contribute positively to educational outcomes from the psychosocial point of view. They promote attitudes and behaviors that are important for the future nursing practice, and therefore bear the hallmarks of positive, mobilizing eustress.

This study has also some limitations. First, a variable regarding previous experiences might be a potential bias of this study as most of the population is professionally active and have experience with stressful situation. Second, the group was small and a larger sample size in future research may improve the fit of the model, offering more robust results. Despite these limitations, the findings from this study provide a rich source of data.

6. Conclusions

Stress levels in the education of nursing students using low and high-fidelity simulation methods can be a factor to reduce the sense of threat and activate professional performance of tasks. Low and high-fidelity simulation sessions do not generate destructive levels of stress. Doubts may arise from the constant testing of the objective (blood) and subjective (KOS-B) levels of stress in the education process.

Nevertheless, constant monitoring of students' perceived stress levels associated with different types of teaching techniques is needed so that lecturers are aware of which teaching methods most effectively support acquiring new skills by students and while at the same time are student-friendly from the point of view of maintaining their mental well-being. Other methods of testing the level of cortisol (from saliva or hair) could help.

Author Contributions: Conceptualization, M.C. (Marta Czekirda), P.M.-O. and A.W.-S.; methodology, M.C., W.T.-B. and A.W.-S.; formal analysis, P.M.-O. and A.W.-S.; investigation, M.C. (Marta Czekirda)., N.J., M.P., M.G. (Mariusz Gnat), J.G., E.G. and M.S.; resources, M.C. (Marta Czekirda), N.J., M.P., M.G. (Mariusz Gnat), J.G., E.G. and M.S.; data curation, M.C. (Marta Czekirda), N.J. and M.P.; writing—original draft preparation, M.C. (Marta Czekirda); writing—review and editing, A.W.-S., P.M.-O., M.G. (Mariusz Goniewicz), M.C. (Mateusz Cybulski), K.K., K.G., A.M.A.-W. and A.K.-M.; visualization, M.C. (Marta Czekirda), P.M.-O., A.W.-S. and W.T.-B. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The approval of the Bioethics Committee for Ethics operating at the Higher School of Economics and Innovation in Lublin was obtained prior to the start of the study (application no. 2019/12/1, dated 19 December 2019).

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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International Journal of
Environmental Research and Public Health

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Citizens' Preparedness to Deal with Emergencies as an Important Component of Civil Protection

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Abstract: The main purpose of this paper is to point out a new approach in evaluating the preparedness of the population of a selected city for civil protection and its response to emergencies. Using new approaches, it evaluates a subjective questionnaire survey in combination with the objective state thanks to a mathematical approach and its subsequent verification on a specific example. The proposed approaches are then verified by experimental surveys in the selected city. The result is a highly adaptable tool that can be set up and adapted to different situations and different types of questionnaires to address the preparedness and safety of the population for emergencies. Thanks to this tool, it is possible to evaluate the subjective opinions of the population and thus gain insight into the assessment of the city's preparedness for emergencies. Subsequently, we can set the prevention and preparedness of the population in the city on the basis of the obtained outputs, which potentially has a fundamental influence on the response after the occurrence of an emergency. Improving preparedness in the area of civil protection shall not only be reflected in the response and minimization of the consequences of the emergency, but also in the emotional security of the population.

Keywords: security; safety; crisis management; risk management; emergencies; emergency preparedness; disasters

Citation: Kubás, J.; Bugánová, K.; Polorecká, M.; Petrlová, K.; Stolínová, A. Citizens' Preparedness to Deal with Emergencies as an Important Component of Civil Protection. *Int. J. Environ. Res. Public Health* **2022**, *19*, 830. https://doi.org/10.3390/ijerph19020830

Academic Editors: Mariusz Goniewicz and Timothy W. Collins

Received: 14 November 2021
Accepted: 11 January 2022
Published: 12 January 2022

1. Introduction

The preparedness of the population to deal with emergencies is now of growing importance. The increasing population density, growing dangers (anthropogenic events—accidents, increasing frequency of emergencies), and urban growth call for risk analysis strategies (including hazard, exposure, and vulnerability factors) in urban areas [1,2]. At the same time, it is necessary to ensure that citizens respond adequately to emerging emergencies. Pirlon (2020) states that local authorities need to make the necessary changes to meet the future challenges by reducing the vulnerability of people and the urban environment [3]. The role of cities is even more important given that more than a half of the world's population lives in urban areas. According to the UN, by 2050, up to 68% of the world's population will live in cities [4].

Some authors state that according to the Focus on Urban Risk of International Federation of Red Cross and Red Crescent Societies, cities and municipalities should pay more attention to the most vulnerable social groups when implementing their disaster risk reduction policies in areas of urban development and expansion (namely in poor and marginalized groups) in order to avoid structural and socio-economic barriers [5,6]. Moisidi (2018) states that the EU civil protection legislation has placed more emphasis on disaster prevention and preparedness since 2013, with a particular focus on risk assessment and risk management planning [7].

The risk is the probability that some results will have a negative impact on people, systems, or assets, which is usually displayed as a function of the combined effects of hazards, assets, or people at risk and the vulnerability of these exposed elements [8,9]. The concept of risk is closely related to the concept of danger, as the risk consists of danger and vulnerability, i.e., it depends on the intensity of the danger and the level of vulnerability. Dangers can have different impacts on individuals, groups in a society, or certain areas, e.g., urban regions. Vulnerability determines the level of impact intensity, and it can be further divided into exposure and manageability [10–12].

As disaster risks are strongly linked to social vulnerability, the impact assessment needs to be looked at from the societal perspective [13–15]. Research that examines the socio-psychological aspects of emergency management reveals much about non-technical/rational-analytical factors that affect individual and community preparedness, emergency decisions, warnings, and evacuation responses [16]. The role of the local population is topical for local disaster risk reduction because, despite socio-economic constraints, the local people can respond, recover, and deploy activities to face emergencies [17,18].

Much literature is devoted to examining risk perceptions and previous experience in influencing public evacuation behavior, and the link between the risk awareness and preparedness, informing the public about scientific uncertainty and the likelihood of risk, drafting a risk report, and so on [19]. It is necessary to know what the population perceives as a risk and what type of information they need. This information must be related to the specific risk of the particular area [20]. Measures to prepare, prevent, and adapt these provisions are based on the emergencies themselves; it is necessary for the population to be clearly informed about the risks to which they are exposed [5].

Ainuddin (2012) argues that risk awareness and preparedness can affect people's vulnerability, as poor cognizance on their part can significantly worsen their vulnerability [21]. Preparedness can be understood as the knowledge and capabilities developed by entities (individuals and organizations) to effectively anticipate, respond to, and recover from the effects of disasters. Disaster awareness and household preparedness are key to reducing the negative effects of a disaster [22].

In the context of disaster risk management, disaster risk is influenced by broader national and global factors; however, it is formed at the local level [23]. There are no initiatives, policies, or strategies in Slovakia in the area of increasing the resilience of its society to disasters. Similarly, there is a lack of initiatives that would lead to any strategic development of the population's preparedness in this respect. The training of young people (university students) and adults for disaster protection is carried out (only to a limited extent) by district authorities, legal entities, and natural persons—entrepreneurs [24,25].

International experience shows that campaigns have emphasized the importance of disaster kits. For example, the Australian government has guidelines for emergency kits, updates of alerts, and warnings; it also carries out disaster education through schools and ongoing research. The American government holds a 'Get10' campaign that publicizes a disaster kit. The Canadian government provides guidelines for household emergency kits, and it organizes the national Emergency Preparedness Week annually to promote emergency preparedness through local events and media coverage. In Nepal, organized training programs and guidelines are provided for the preparation of emergency kits and family emergency planning [26–30]. Despite the important role played by the National Civil Protection Organization, several case studies in Italy from north to south show that communication and cooperation between institutions and citizens is at a high level only immediately after the disaster [5,31–33]. Nevertheless, the focus on the places and the people affected tends to gradually fade and then completely disappear until the next disaster occurs [34].

To protect life, health, and property in the event of an emergency, it is necessary to analyze the potential threat, take measures to reduce the risks of the emergency, and to identify procedures and actions in dealing with the consequences of such emergencies [35]. In this whole process, it is necessary to focus on the opinion of the population and their

preparedness to handle emergencies as well as use their opinions to improve it. Several scientific papers emphasize the need to examine these views. They also emphasize the need to further use the views and thus improve the level of the population preparedness by means of various tools [36–38]. Germany, for instance, is aware of the use of the potential of the population and their views, where the Federal Office for Civil Protection and Disaster Relief under Section 4 of the Civil Protection and Disaster Relief Act has significantly strengthened and developed the social science perspective in civil society protection in recent years. The socio-scientific dimension of crisis management will be further developed as a situational picture of the population's behavior and will be more significantly implemented in risk prevention. One of the main topics is how to possibly use scientifically proven knowledge about the behavior of the population, its (information) needs, and self-defense capabilities in crises and disasters for decision-making processes in crisis management [39]. There are several approaches to obtaining such an opinion correctly. Some authors use the Person-Relative-to-Event theory model to assess the readiness of the population, with which they support their research claims [40]. Other authors, by contrast, point at the possibility of using The Protective Action Decision Model to examine threat perception [41]. The most common problems in applying these methods and approaches are the complexity of their use as well as their low informative value. Therefore, an absence of the use of specific opinions of respondents occurs quite often. As a result, it is important to develop an appropriate metric that can be used to assess the current state of preparedness of the population. When obtaining respondents' opinions, it is very important to ask questions correctly. They must be comprehensible and have the necessary expressive value. The questions should focus on the identification of respondents, their subjective opinions, theoretical knowledge, and on the possibilities of improving their preparedness.

According to Act 42/1994 on Civil Protection, a natural person is entitled to an early warning of an imminent danger and immediate assistance in endangering his/her life, health, and property; he/she has the right to evacuate and hide, and to be informed about the method of protection. They also have the right to create the conditions to provide civil protection training, the aim of which is to enable them to acquire the necessary knowledge and skills for protection and to help others in need [25]. Our area of interest is the preparation of the population for self-protection, which is ensured through the Decree of the Ministry of the Interior No. 303/1996. It understands the provision of preparation for civil protection and mutual assistance as a purposeful and continuous process of preventive-educational and promotional activities; theoretical as well as practical training enables individuals to acquire the necessary knowledge, skills, and habits for self-protection and assistance to others in need [42]. The main forms of population preparation for self-protection and mutual assistance are as follows [42]:

- information and advisory service;
- programs broadcasted on the radio and television;
- publishing activities (professional publications, brochures, puzzles, etc.);
- preventive-educational and promotional activities (exercises, competitions, exhibitions, and excursions);
- theoretical and practical training;
- publication of information in an electronic form.

In order to assess whether the preparation of a population is effective and at a sufficient level, it is necessary to determine the state of the knowledge and awareness of the population. Therefore, the aim of this article is to create a way to assess the preparedness of the population for emergencies and to replicate it in the selected municipality.

2. Materials and Methods

To increase the level of preparedness of the population for emergencies, it is necessary to be able to assess the current situation. For these needs, a simple tool has been developed to assess the total rate of the respondents' preparedness for emergency. So, it is the basis for a purely political decision on a possible financial investment in the field of civil protection.

This basis should be as simple and comprehensible as possible. This leads to the need for data aggregation, optimally up to a single number. Accordingly, the methodology of evaluation of the questionnaire is conceived—an illustrative method of using data aggregation was used.

The proposed instrument has several limiting conditions and expected errors (uncertainties). Sampling-related errors include data collection that has been performed under conditions that cannot be repeated, the non-existent method of selecting the respondents who answered the questionnaire and therefore there is no possibility to repeat the structure of the respondents, and the unrepresentativeness of the structure. The reason for the chosen sampling was time and economic savings. Non-sampling errors include the unreachability of respondents, their reluctance to communicate, data processing errors, data analysis errors, inaccurate answers from respondents, and difficulty quantifying.

These errors are present in every survey, regardless of sample size. The survey was used mainly to verify the metrics. The results are available to the city and serve to quickly verify the current state. For more accurate results, it is planned to allocate more funding and resources to replicate this research with an emphasis on representativeness. Such research should be repeated at regular intervals to compare how new measures and communication by the city are perceived by residents and how their readiness changes.

A questionnaire was developed to take advantage of the population's views on security and their preparedness for emergencies. The questionnaire's very form enables it to quickly and efficiently obtain answers from a number of respondents. The questionnaire consists of several types of questions. It is essential to identify the respondent, which will allow for comparing the answers in different groups and to propose measures with regard to the results of specific groups. Other types of questions focused on objective and subjective indicators. These issues were based on a generally binding legal regulation in Slovakia, which addresses the issue of civil protection of the population. Among others, they contain and describe the extraordinary events that may occur in the given area. In the event that the research takes place in another country, it is of course necessary to adapt the questions to its generally binding regulations concerning the given subject matter. The questionnaire is supplemented by a question that seeks an opinion on informing about the issues by the municipality and a question that focuses on the form of informing. It is the findings concerning the form of informing that will enable the municipality to better concentrate on specific groups and choose appropriate forms. The questions were closed, and some could be marked on the Likert Scale. In some, the possibility of "I do not know" (meaning the respondent cannot judge) is added so that the respondent is not forced to mark an answer about which he/she is not convinced.

The city of Žilina was selected to verify the questionnaire, where the questionnaire was assessed and shared on the official city website in cooperation with the city representatives. The questionnaire aimed at assessing the preparedness of the inhabitants of the city of Žilina for extraordinary events is shown in Table 1. The city of Žilina functions as the center of northwestern Slovakia and is the fourth largest city in the Slovak Republic. It is the seat of the bodies of the Žilina self-governing region, one of the eight regions of the Slovak Republic. It covers an area of 80.03 km^2 and has a population of 82,494 inhabitants. It is located in the valley of the river Váh, in the Žilina Basin, at the confluence of Váh with the rivers Kysuca and Rajčianka. The basin is formed by Tertiary sediments—conglomerates with inserts of soft sandstones of the Carpathian Paleogene. Relatively wide river floodplains stretch along Váh and Rajčianka, accompanied on the sides by Pleis-Tocene gravel terraces. The Žilina Basin is located among the Malá Fatra, Strážovské vrchy, Súľovské vrchy, Javorníky, and Kysucká vrchovina mountains. The average air temperature in July reaches +18 °C, in January −4 °C. The annual average precipitation is 650 to 700 mm, mostly in June and the first half of July. The snow cover is 60 to 80 days a year [43]. In our opinion, what will make it possible to verify the new metric to determine the preparedness of the population for emergencies and to suggest ways to improve it is the research on a specific city.

Table 1. Questions from the questionnaire.

No.	Question	Answer
1	Place of residence	Žilina/Other
2	Age	
3	Sex	Female/Male
4	Highest level of education	Primary/Secondary without the graduation exam/Secondary with the graduation exam/Bachelor's degree/Master's degree/Doctoral degree
5	Do you think that you can react appropriately in the event of the following natural disasters?	
	Floods and inundations	Yes/Rather yes/Rather no/No/I do not know
	Hailstorm	
	Swelling	
	Landslides	
	Snow calamities and avalanches	
	Extensive icing	
	Earthquakes	
6	Do you think that you can react appropriately in the event of the following accidents?	
	Fires and explosions	Yes/Rather yes/Rather no/No/I do not know
	Leaks of hazardous substances, preparations, and wastes, petroleum products with subsequent contamination of land, air, watercourses, drinking water sources, and groundwater	
	Damage to distribution lines, their equipment, and transmission lines	
7	Do you think that you can react appropriately in the event of the following disasters?	
	Major air, rail, ship, and road accidents associated with fires or leaks of hazardous substances	Yes/Rather yes/Rather no/No/I do not know
	Nuclear accident	
	Damage to water structures	
8	Do you think that you can react adequately in the event of a terrorist attack?	Yes/Rather yes/Rather no/No/I do not know
9	The current threats to public health of the second degree in COVID-19 coronavirus SARS-CoV-2 is due to:	The occurrence of a communicable disease, suspicion of a communicable disease or suspicion of death of a communicable disease above the expected level/Release of chemicals endangering life, health, environment, and property/Leakage of microorganisms or toxins from enclosed spaces
10	Do you think that you can react appropriately in the event of a threat to public health of the second degree?	Yes/Rather yes/Rather no/No/I do not know

Table 1. *Cont.*

No.	Question	Answer
11	The population is warned by warning signals. Do you know what signal the sirens are announcing?	
	General threat	Two-minute fluctuating tone/Six-minute steady tone/Two-minute steady tone/I do not know
	Water threat	
	The end of the threat or the end of the effects of the emergency	
	Testing the operability of population warning systems after informing the population about the time of the test through the mass media	
12	The evacuation is announced through the mass media and is revoked if the reason for which it was announced has passed. Evacuation is divided into:	A short-term evacuation with a possible return of the evacuees within 24 h and a long-term evacuation with a possible return of the evacuators after 24 h/A short-term evacuation with a possible return of the evacuators within 48 h and a short-term evacuation with a possible return of the evacuators after 48 h/A short-term evacuation with a possible return of the evacuators within 72 h and a long-term evacuation with a possible return of the evacuators after 72 h/I do not know
13	The weight of the evacuation baggage may be at most:	15 kg + 5 kg of hand luggage for an adult; 5 kg + 5 kg of hand luggage for a child/25 kg + 5 kg of hand luggage for an adult; 15 kg + 3 kg of hand luggage for a child/25 kg + 5 kg hand luggage for an adult; 15 kg + 5 kg hand luggage for a child/I do not know
14	Do you know what the population protection plan is?	A document containing tasks, measures, and procedures to ensure the protection of the population in the event of an emergency/A document containing a plan for the population how to protect themselves/A document containing the description of all emergencies in the municipality with a proposal for a better solution/I do not know
15	The resident has the right:	To an early warning of an imminent danger, to evacuation and concealment, to information about the method of protection, and to an immediate assistance in case of danger to life, health, and property/Only to an immediate assistance in case of danger to life, health and property/Only for early warning of imminent danger and for evacuation or hiding/Do not know
16	Do you know where there is a space in your area for people to hide (the so-called civil protection cover)?	Yes/No
17	To what extent are you interested in civil protection and population protection on your own initiative?	I am intensely interested, I look for professional publications and news in this area/I am interested, I look for interesting things on the Internet and in the media/I am passive, I only accept information from the media/I am not interested at all

Table 1. *Cont.*

No.	Question	Answer
18	Have you seen or searched for information on civil protection and population protection at (you can also mark more than one answer):	The website of the city of Žilina/The website of the higher territorial unit of Žilina/The website of the Ministry of the Interior of the Slovak Republic/I have not seen any of these/I have not searched/Other—please specify
19	Do you think that the city of Žilina sufficiently informs its inhabitants about civil protection and population protection?	Yes/Rather yes/Rather no/No/I do not know/ Other—please specify
20	What form of information about civil protection and population protection would you prefer (it is possible to indicate more than one answer):	Creation of a clear website with all the necessary information/Courses or trainings/Lectures/Information leaflets/Available book publications/On the local TV or in the local newspapers/On Facebook, Instagram/None/Other—please specify

The questionnaire survey during the primary data collection included those citizens who duly filled in and sent the completed questionnaire on the official website of the city of Žilina in the period from 1 July 2021 to 30 June 2021. The questionnaire was also shared through social networks and targeted the inhabitants of Žilina. The reason for collecting the necessary data was to verify the metric on the results of the questionnaire survey in a particular city. The intention was also to verify the suitability of the questions for research needs. The completed questionnaire survey meant no costs for the city and was not time-consuming. The disadvantage was that the obtained sample did not meet the conditions of representativeness. If the research is repeated, the city will need to set aside time and resources, among other things, to ensure the representativeness of the survey, so that the results are as relevant as possible. On the second level, only those questionnaires were processed and selected from the collected questionnaires, where the respondents answered the question number 1 as citizens of the city of Žilina. These circumstances define the first and second levels of inclusive and exclusive criteria. Therefore, the key to assessing the total preparedness of the inhabitants of the city of Žilina for emergency was the creation of a tool that will enable this preparedness to be "measured" on the basis of the data obtained from a questionnaire survey. That is, the creation of a metric that will make it possible to express the preparedness of the population in a simple and maximally comprehensible way, preferably with a single number. At the same time, however, it is necessary to obtain information on the structure of preparedness. Both sorts of data are needed in order for the management of the city of Žilina not only to know how prepared its inhabitants are for emergency, but also to obtain information on what to focus on so that their preparedness can be increased if necessary. The composition of the questions was based on generally binding regulations [25,44]. In the case of conducting surveys in other countries, it is appropriate to modify the issues according to the particular legal regulations. The metric is designed to be repeated in other municipalities and countries.

It is first necessary to introduce the appropriate quantities and define the appropriate metrics. To this end, the questions in the questionnaire were divided into several groups according to their nature. As a result, the key issues for determining total preparedness were divided according to their nature into two groups: objective and subjective. The distribution was chosen because of the complete assessment of total preparedness, which typically consists of both the objective knowledge of the population (e.g., relevant laws, decrees, and standards) and the fully subjective ability of each individual to respond appropriately to an emergency.

The objective questions (questions 9, 11–16) indicate only the innocence or ignorance of the corresponding theoretical knowledge in the field of emergency preparedness. Each

correct answer was awarded one point in the evaluation and incorrect answers were awarded zero points. The maximum possible (non-standard) value for the objective criteria O_{max} is 10 points (question no. 11 has four sub-questions), while O_i is the total achieved point value for the objective criteria for the i-th respondent.

The subjective questions (questions 5–8, 10, 17–18) indicate for the given respondent to what extent he/she is able to adequately respond to the given type of emergency and whether he/she is interested in the issue of civil protection. They thus express their subjective evaluation of their own preparedness. Maximum (non-standard) point value for the subjective criteria of the i-th respondent S_{max} is 17 points. S_i is the total achieved point value for the subjective criteria of the i-th respondent.

As the questions are of a different nature, it was necessary to set the evaluation of the answers correctly. The evaluation of individual answers is given in Table 2.

Table 2. The evaluation of individual answers.

Question No.	Answer	Value
9, 11, 12, 13, 14, 15 16	Correct answer Not right answer	1 0
5, 6, 7, 8, 10	Yes Rather yes Rather no No; Do not know	1 0.5 0.25 0
17	I am intensely interested I am interested Passive I am not interested	1 0.5 0.25 0
18	Any answer No answer	1 0

Before using the mathematical apparatus itself, it is necessary to define the quantities. All quantities gradually used in the mathematical apparatus are shown in Table 3.

Table 3. Qualification of the quantities used.

Quantity	Symbolized by	Note
Number of respondents	N	$n \in \mathrm{N}$
i-th respondent	i	$i \in \{1, \ldots, n\}$
Maximum value of subjective criteria for a given respondent	S_{max}	$S_{max} = 17$ pts.
Maximum value of objective criteria for a given respondent	O_{max}	$O_{max} = 10$ pts.
The total achieved value of the subjective criteria of the i-th respondent	S_i	$S_i \in \langle 0 \text{ pts.}, S_{max} \rangle$
The total achieved value of the objective criteria of the i-th respondent	O_i	$O_i \in \langle 0 \text{ pts.}, O_{max} \rangle$
Total rate of the preparedness of the i-th respondent for emergency	P_i	$P_i \in \langle 0 \text{ pts.}, 100 \text{ pts.} \rangle$
Metric—the total rate of the respondents' preparedness for emergency	P	$P \in \langle 0 \text{ pts.}, 100 \text{ pts.} \rangle$
The total difference rate of the preparedness of the i-th respondent for emergency	R_i	$R_i \in \langle 0 \text{ pts.}, 100 \text{ pts.} \rangle$
Metric—the total difference rate of the respondents' preparedness for emergency	R	$R \in \langle 0 \text{ pts.}, 100 \text{ pts.} \rangle$

The introduction of these quantities was a necessary step in the correct definition of both metrics P and R. Metrics P and R are functions of S_i and O_i: $P = P(S_i, O_i)$,

$R = R(S_i, O_i)$. Each of the quantities S_i and O_i has a different point range, so it is advisable to standardize them first. Therefore, "standardized" quantities $\overline{S}_i$ and $\overline{O}_i$ are introduced:

$$\overline{O}_i = 100\frac{O_i}{O_{max}},$$

$$\overline{S}_i = 100\frac{S_i}{S_{max}},$$

where $\overline{S}_i$, $\overline{O}_i \in I_{100} = \langle 0 \text{ pts.}, 100 \text{ pts.} \rangle i \in \{1, \ldots, n\} = I_n$.

The set of quantities $\overline{S}_i$ and $\overline{O}_i$ forms a coordinate system on the space $V = I_{100} \times \cdots \times I_{100} = I_{100}^{2n}$. It is now possible to introduce new coordinates P_i and R_i in space V:

$$P_i = \frac{1}{2}(\overline{S}_i + \overline{O}_i),$$

$$R_i = \frac{1}{2}(\overline{S}_i - \overline{O}_i) + \frac{\max\{I_{100}\}}{2}.$$

The last constant term on the right side of the second of the above relations shifts the domain from the interval $\langle -50 \text{ pts.}, 50 \text{ pts.} \rangle$ to the interval $\langle 0 \text{ pts.}, 100 \text{ pts.} \rangle$. If this term were not there, it would not be coordinates on space V. The P_i coordinate indicates the overall degree (subjective and objective) of the i-th respondent's emergency preparedness. The R_i coordinate indicates the total difference rate (subjective and objective) of the i-th respondents emergency preparedness.

The metric P is defined as the mean. The sets of values $\{P_i\}_{i \in I_n}$ and $\{R_i\}_{i \in I_n}$ can be understood as the realization of two random variables. Therefore, it makes sense to determine the numerical characteristic of these random variables (e.g., mean or variance) or to verify that they have the character of some known type of data distribution of all P_i:

$$P = E\Big(\{P_i\}_{i \in I_n}\Big) = \frac{1}{2n}\sum_{i=1}^{n}(\overline{S}_i + \overline{O}_i).$$

The metric R is now defined as the mean of all R_i:

$$R = E\Big(\{R_i\}_{i \in I_n}\Big) = \frac{1}{2n}\sum_{i=1}^{n}(\overline{S}_i - \overline{O}_i) + \frac{\max\{I_{100}\}}{2}.$$

Metric P represents the total rate (subjective and objective) of the respondents' preparedness for emergency. The interpretation of their significant values is as follows:

- $P = 0$ pts.—the respondents' complete unpreparedness for emergency,
- $P = 50$ pts.—the respondents' half-preparedness for emergency,
- $P = 100$ pts.—the respondents' complete preparedness for emergency.

Metric R represents the total difference rate of the respondents' preparedness for emergency. The interpretation of their significant values is as follows:

- $R = 0$ pts.—purely subjective preparedness for emergency (no objective preparedness);
- $R = 50$ pts.—the same subjective and objective preparedness for emergency;
- $R = 100$ pts.—purely objective preparedness for emergency (no subjective preparedness).

Furthermore, for 0 pts. $\leq R <$ 50 pts., the objective respondents' preparedness for emergency prevails over their subjective one. By contrast, for 50 pts. $< R \leq$ 100 pts., the subjective respondents'preparedness prevails over their objective one.

The main motivation for the creation of P and R metrics was the inclusion of objective and subjective criteria in the simplest possible form and, moreover, so that, if necessary, the distribution of "importance" between the objective and subjective criteria could be easily adjusted. Another motivation for the creation of the P and R metrics in this form was the comprehensibility of the total evaluation and the related easy interpretability of the obtained results. For this reason, the whole concept is created in such a way that both

metrics take values from the interval ⟨0 pts., 100 pts.⟩, and the same importance was set for subjective and objective criteria. This is also evident from the fact that the relations for P_i and R_i have the same coefficient $\frac{1}{2}$ for the quantities $\overline{O}_i$ and $\overline{S}_i$. Consequently, both quantities have the same "weight". Weight adjustment—the adjustment of the importance of subjective and objective criteria—is then performed by adjusting the coefficients in the relationships for pro P_i and R_i. The coefficients should be chosen so that their sum is equal to one, as in the case described above.

The evaluation of P and R metrics, while applying the selection criteria from questions 2–4 (see Table 1) and their mutual comparison, will provide additional information about the total preparedness and differential preparedness of respondents for emergency for groups of respondents meeting individual criteria (gender, age, education).

One of the possible problems in assessing the results of the questionnaires is the problem of the representativeness of the set of respondents. This problem is relatively complex, so in order to assess the representativeness of the sample of the population of the city of Žilina, space was devoted to questions of a classification nature (questions no. 1–4). Based on the answers to question no. 1, those respondents who stated a residence other than the city of Žilina were excluded. By evaluating the answers to questions 2–4, it is possible to determine whether at least the necessary, but not sufficient, conditions for the representativeness of the sample of the examined population are met.

To obtain additional information, the questionnaire lists questions 19 and 20, which are semi-open and open. Their purpose is to obtain additional information on the views of respondents on the preferred ways of being informed about civil protection and population protection.

3. Results

The first questions made it possible to identify the respondents. Question 1 of the questionnaire serves as an exclusion criterion. Only the part of the respondents who stated in the questionnaire that they were from Žilina was included in the calculations. A total of 340 respondents took part in the questionnaire survey, while there were 316 respondents from Žilina, which is about 93% of all respondents. The basic results obtained from these questions of the questionnaire are shown in Table 4.

Table 4. Results of sorting questions.

Respondents	**From Žilina**	**Outside Žilina**					**Total**
Number [%]	92.94	7.06					100
Age	<20	20–29	30–39	40–49	50–59	60<	Total
Number [%]	4.43	43.04	26.58	16.77	5.38	3.80	100
Sex	Female	Male					Total
Number [%]	58.86	41.14					100
Education	Primary	Secondary without the graduation exam	Secondary with the graduation exam	Bachelor's degree	Master's degree	Doctoral degree	Total
Number [%]	3.78	4.11	50.32	12.97	23.73	5.06	100

The key information about the set of obtained data needed to assess the total preparedness of the inhabitants of the city of Žilina for extraordinary events consists of sets of values $\{P_i\}_{i\in I_n}$ and $\{R_i\}_{i\in I_n}$. Where P_i is the total rate (subjective and objective) of the preparedness of the i-th respondent for emergency and R_i is the total difference rate (subjective and objective) of the preparedness of the i-th respondent for emergency.

The most fundamental quantity for the total assessment of the preparedness of the population of the city of Žilina for emergency is the metric P, hence the total rate (objective and subjective) of the respondents' preparedness for emergency. An additional quantity is

the metric R, hence the total difference rate (subjective and objective) of the respondents' preparedness for emergency. These and other numerical characteristics for $\{P_i\}_{i\in I_n}$ and $\{R_i\}_{i\in I_n}$ are listed in Table 5.

Table 5. Basic numerical characteristics $\{P_i\}_{i\in I_n}$ and $\{R_i\}_{i\in I_n}$.

Quantity	Minimum [pts.]	Lower Quartile [pts.]	Median [pts.]	Upper Quartile [pts.]	Maximum [pts.]	Mean Value [pts.]	Variance [pts^2]
$\{P_i\}_{i\in I_n}$	7.21	29.08	38.38	49.12	77.06	39.89	203.77
$\{R_i\}_{i\in I_n}$	17.50	39.12	46.18	52.68	79.85	46.22	124.63

Note: $P_i, R_i \in \langle 0\ pts.,\ 100\ pts.\rangle i \in \{1,\ldots,n\}$.

Table 4 and the method of introducing metrics P and R show that:

$$P = 39.89\ points,$$

$$R = 46.22\ points.$$

Metric P, hence the total rate (subjective and objective) of the respondents' preparedness for emergency, was defined as the mean value of all P_i. From Table 4, it becomes obvious that the value of metric P, is 39.89 points. According to the proposed evaluation in Chapter 2, the result falls within the interval between the complete respondents' unpreparedness for emergency and the respondents' half-preparedness for emergency. The resulting value is closer to respondents' half-preparedness for emergency. The result can generally be interpreted as a relatively low rate of total emergency preparedness. According to Table 4, the R metric, hence total difference rate (subjective and objective) of the respondents' emergency preparedness, acquires the value of 46.22 points, which, according to the evaluation from Chapter 2, is in the interval between completely objective emergency preparedness and the same subjective and objective emergency preparedness. The result can be interpreted in such a way that the objective preparedness of respondents slightly prevails over the subjective one. Another authoritative data is the variance of P_i values, which is 203.77 pts^2. It can be interpreted as rather higher, i.e., there is a relatively large difference among the knowledge of individual respondents. From the value given in the upper quartile column, it shows that 75% of respondents achieved a score below 50 points. The proximity of the mean and median of all P_i indicates that the distribution of data is almost symmetric. The maximum achieved value of P_i is 77.06 points, which means that the best of the group of respondents does not reach even 80% preparedness for emergency.

Other information that can be obtained from the questionnaire survey is the information about metrics P and R, that is the total rate (objective and subjective) of the respondents' emergency preparedness for groups respondents by gender, age, and education (see Table 1, questions 2–4). The values are given in Table 6.

Due to age, the metric P is relatively balanced in all categories. The only group showing an above-average value of the total rate of the emergency preparedness is the aged 60 and over. At the same time, the objective preparedness clearly outweighs the subjective preparedness in this group (metric R). Subsequently, the age category over 60 years feels the least subjectively prepared for emergency, but in the total result it performs above average in their objective knowledge. In terms of gender, the total rate of emergency preparedness is higher for the male according to the results, which can be explained by a higher level of subjective feeling of preparedness, as shown by metric R. Depending on education, the category of secondary school without the graduation exam deviates significantly, where the metric P is 30.77 points, which is the lowest value of all groups. The category of secondary schools can be understood as a remote value, while the trend form metrics P then increases with education for the remaining values. The subjective emergency preparedness of the remaining groups decreases with an increasing education at the expense of the objective

one. These data can be valuable in targeting additional education of the population by the representatives of the city of Žilina in order to improve the resulting total score of emergency preparedness.

Table 6. Metrics P and R for individual sorting characteristics.

Age [Years]	**<20**	**20–29**	**30–39**	**40–49**	**50–59**	**60<**
P [pts.]	39.23	40.46	39.98	38.53	37.23	43.37
R [pts.]	53.52	47.30	44.51	44.38	51.35	38.37
Sex	Female	Male				
P [pts.]	38.48	41.92				
R [pts.]	44.71	48.38				
Education	Primary	Secondary without the graduation exam	Secondary with the graduation exam	Bachelor's degree	Master's degree	Doctoral degree
P [pts.]	40.33	30.77	39.04	41.51	40.97	46.22
R [pts.]	53.66	46.15	46.65	45.65	45.24	42.47

Note: $P,\ R \in \langle 0 \text{ pts.}, 100 \text{ pts.} \rangle$.

Questions no. 2–4 are mainly used for a possible assessment of the representativeness of the set of respondents as a sample of the population of the city of Žilina (see Table 1). In order for the result of the metric *P* to have a completely undistorted and meaningful value, it is necessary to ensure the representativeness of the obtained data set. From the data on gender distribution, it can already be concluded that the necessary condition of representativeness is not met. Assuming that the questionnaire was filled in more by those interested in the given issue, from whom a higher level of knowledge about the issue can be expected, it can be concluded that the real total rate of the emergency preparedness will actually be lower than found. Therefore, it can be expected that the value of the total determined rate of the emergency preparedness of the inhabitants of the city of Žilina will be the upper limit of the real value of this preparedness. Although the representativeness of the population sample was not accurately maintained, the data obtained can still be used to evaluate and test the proposed *P* and *R* metrics with the above limitation. The result is the motivation to adjust the methodology of data acquisition so that the necessary conditions for the representativeness of the obtained data set are met.

4. Discussion

The article focuses on a new approach in evaluating the preparedness of the population for civil protection and its response to emergencies. The proposed approach is then verified by experimental surveys in the Žilina city. Thanks to this tool, it is possible to evaluate the subjective opinions of the population and thus gain input to the assessment of the city's preparedness for emergencies. Based on the obtained outputs, it is possible to set the prevention and preparedness of the population in the city by the representatives of the Žilina city, which has a fundamental influence on the response after the occurrence of an emergency.

The research results show some important information for the city of Žilina. The results of the survey describe the relatively low level of emergency preparedness (P = 39.89 points out of 100) of the inhabitants of the city of Žilina. The city of Žilina should therefore pay attention to increasing the level of population prevention education of its inhabitants, for example, by targeting the groups that showed the weakest results in the questionnaire. Although the sample examined did not meet the criterion of representativeness, the information obtained can still be very valuable for the city, as it will help the city to obtain a basic overview of the views of its residents on the issue in a short time. The crisis management staff of the city of Žilina has the results of the investigation at their disposal and will use them to improve the preparedness of the population to deal with emergencies. We expect

the research to be repeated in the future. Emphasis will be placed on the representativeness of the sample in order to obtain most relevant information needed to improve the preparedness of all citizens for various emergencies.

Just over 2.42% of respondents are convinced that the city of Žilina provides sufficient information on civil protection and population protection (question 19). In the questionnaire survey, as many as 32.02% of the respondents stated that the city of Žilina tends to inform its inhabitants insufficiently in the field of civil protection and population protection. The highest percentage of respondents shared that they did not know whether informing on the part of the city was sufficient. The results of the survey on informing the city of Žilina about civil protection and population protection are shown in Table 7.

Table 7. Respondents' sense of awareness of the city of Žilina in the field of civil protection and population protection.

Question	Answer				
	Yes	**Rather Yes**	**Rather No**	**No**	**I Do Not Know**
Do you think that the city of Žilina sufficiently informs its inhabitants about civil protection and population protection?	2.42%	9.06%	32.02%	21.75%	34.75%

The results of question 20 indicate that the respondents stated the creation of a transparent website with all the necessary information (24,69%) as the most preferred form of information, followed by Facebook and Instagram (20.22%) and an information leaflet (15,30%). The city of Žilina should focus mainly on creating a clear and concise website that would inform the inhabitants of the city about the basics of population protection and, most importantly, how they should behave in the event of specific emergencies threatening the region. The respondents lack comprehensive information on the immediate response to individual extraordinary events, which would be available on the website of the city of Žilina. Younger respondents would also appreciate the information on social networks. Still, it is questionable how to set the content of the reports on the protection of the population so that they are not completely lost in the flood of much more interesting daily news. The fact that respondents often follow social networks does not mean that they look for practical information on them. When creating an information leaflet, it is essential to solve the distribution to individual households in particular and to choose such a visual form that the inhabitants of the city would be attracted, and the leaflet will not end up unnoticed directly in the sorted waste. In comparison, book publications (2.12%), courses or trainings (6.15%), and lectures (5.70%) are the least sought-after forms of information int the field of civil protection and population protection. The respondents show minimal interest in these forms of education in the field of population protection. It is probably not very important for the city of Žilina to invest time and money in the least required forms of education and, conversely, it should focus on the forms that the respondents preferred according to the questionnaire survey instead. The specific results are shown in Table 8.

When asked about the preferred form of education, the respondents were also given an opportunity to verbally complete the missing form. Four respondents took the opportunity and recommended a mobile phone application, billboards, or a clear guide for each household. One respondent pointed to the need for an easy-to-understand language for scholars or people with disabilities.

Table 8. Preferred form of information about civil protection and population protection.

Preferred Form of Information	Percentage
1. A transparent website	24.69%
2. Courses or training	6.15%
3. Lectures	5.70%
4. Information leaflets	15.30%
5. Available book publications	2.12%
6. On the local TV or radio	13.97%
7. In the local newspaper	11.17%
8. Facebook, Instagram	20.22%
9. None	0.68%

Due to the age of the respondents, the age group of 60 and over reached the above-average value of the total rate of the emergency preparedness. The reason for the result may be, among other things, the fact that the given age group regularly completed the so-called military education as a compulsory part of school attendance in the past. However, for example, official sources of the Fire and Rescue Service of the Czech Republic (HZS ČR) show that seniors tend to be the most vulnerable group in emergencies, due to their reduced mobility or slower evaluation skills [45]. As a result, since 2010, the HZS ČR has decided to pay more attention to this group of the population than before. A sufficient amount of free time, the desire to learn something new, the willingness not to be indifferent to their surroundings, and enough life experience predispose the group of seniors to a long-term and quality education in the field of civil protection and population protection.

In connection with education, the categories of secondary education without the graduation exam deviate from the results of the questionnaire survey. The respondents from this group achieved the lowest rate of preparedness for emergencies. If the city of Žilina is interested in increasing the level of emergency preparedness of the population, it should start with this category and can use the results of the last question of the questionnaire survey. In the question, the respondents directly identified those forms of information about civil protection and population protection that are close to them, i.e., those which they would prefer themselves. The obtained results of the preferred form of information on civil protection and population protection for the group of respondents from the category of secondary education without the graduation exam are shown in Table 9.

Table 9. Preferred form of information about civil protection and population protection in the category of secondary education without the graduation exam.

Preferred Form of Information	Percentage
1. A transparent website	26.92%
2. Courses or training	7.69%
3. Lectures	3.85%
4. Information leaflets	15.38%
5. Available book publications	3.85%
6. On the local TV or radio	15.38%
7. In the local newspaper	11.54%
8. Facebook, Instagram	15.38%
9. None	0%

A comparison of Tables 7 and 8 clearly shows that the respondents belonging to the category of secondary education without the graduation exam prefer the same forms of information as all other respondents, regardless of the classification of respondents into groups according to education. As a matter of fact, if the city of Žilina decides to raise the awareness of its concerns, it should obviously start by creating a transparent website with all the necessary information in the field of civil protection and population protection.

This information should also serve as a potential basis for other municipalities that address similar issues.

The municipality plays an important role in reducing the risk of disasters and emergencies, as it serves as the primary point of contact for its population in terms of subsidiarity and the ability to build resilience. The content and form of preparedness of the population for emergency is chosen by the municipality itself [24,42]. A lack of human and technical resources leads to poor emergency awareness and ineffective implementation of prevention and mitigation strategies at the local level [46].

Higher income and education levels appear to be important indicators of development that can reduce vulnerability and enable citizens to engage in self-protection [47,48]. Education increases people's knowledge about disaster risks and influences their risk perception [49,50]. In addition, public awareness of disaster risk reduction is a key factor influencing their behavioral decisions [51]. However, the communication gap between professionals and lay public can be a problem. There is a need for local authorities and experts to establish the conditions for spreading a culture of awareness of the risks of a given area and to increase the level of security of a particular area through concrete and participatory actions (bottom-up approach). However, communication about natural disasters or emergencies does not only mean informing citizens, but also assessing whether they understood the content of the communication. In fact, everyone who communicates should necessarily be "aware" and informed about the needs and requirements of the community, as well as their level of understanding [20]. Therefore, attention needs to be paid to how people interpret the risks that shape their own experiences, feelings, values, cultural beliefs, and interpersonal and social dynamics [16]. Proper preparation of the population for various unexpected events will increase their safety and can positively influence the response to emergencies and disasters. Consequently, it is necessary for municipalities to know the current state of preparedness of the population and take measures based on them. Such activities can also improve the security environment in which residents find themselves. In the event of a crisis, the prepared population reflects the preparedness of the emergency for various emergencies and disasters [52–54].

What is more, disaster awareness research may indicate a weak or poor perception of the links among people in a given area or may help to clarify the lack of knowledge among the people in a given area [55,56]. In addition to extensive research into disaster risk perceptions and awareness, research is often tied to local conditions. This is due to the specific conditions that endanger the population as well as to the generally binding regulations in the area under assessment [57,58]. Donahue et al. pointed out that local government officials often do not know the views of the population. Another problem is the low informative value of the opinions obtained or the incorrect use of opinions [59]. Appropriately obtained and evaluated opinions of the inhabitants will enable the local government managers and municipalities to adapt the information and educational process so as to improve the readiness of the inhabitants themselves. It is also important to be able to calculate the preparedness of the population, which will allow municipalities to compare how the implemented changes affect the preparedness.

5. Conclusions

In the article, we introduced a new tool that could be used to assess the level of preparedness and awareness of the population in a municipality for emergencies. This tool is a new metric that can be applied to the needs of other municipalities too. The result of the metric is a value that expresses the level of preparedness of the inhabitants of a municipality. The views of the population are included in this metric, which can be obtained by the method of a questionnaire. The questionnaire we created serves the environment of Slovak municipalities, and, in case of repetition in other countries, it should be adjusted according to local conditions. Based on the results, the municipality can determine the right way to further increase information and provide training of the population in this respect. We verified the proposed means in the city of Žilina, where we pointed out the possibility of

verifying the metric in practice. The overall survey and focus of the article are in accordance with the requirements of the legislation of the Slovak Republic [25]. The approach chosen is therefore closely linked to the regional conditions, legislation, and customs in the country and therefore needs to be adapted to the conditions in the country that would possibly use this approach.

Based on the proposed calculations, we can draw clear conclusions from the above stated facts that the city of Žilina and its inhabitants are not sufficiently prepared to respond in the event of various types of emergencies. It is very important to realize that the assessment of this preparedness is based not only on objective facts, but especially on the subjective assessment of the population concerned. Thanks to the presented tool that can be used to evaluate the subjective view of the population in combination with objective factors, we can realistically determine the state of preparedness and also propose adequate measures on that basis. By further developing and adapting the proposed tool, it is possible to respond flexibly and adequately to the state of knowledge and preparedness of the population and thus significantly streamline prevention in the field of civil protection. The point is that a well-informed and educated population in response to an emergency can reduce the burden on rescue services and crisis managers. Moreover, it will also help reduce the consequences of an emergency and thus contribute to the overall security. These facts will also affect the emotional security and quality of living of the population.

Author Contributions: Conceptualization, J.K., K.B., M.P., K.P. and A.S.; methodology, J.K. and A.S.; software, J.K., K.P. and A.S.; validation, J.K., A.S. and M.P.; formal analysis, J.K. and K.B.; investigation, J.K., K.B. and M.P.; resources, J.K., K.B. and M.P.; data curation, J.K., K.B., M.P., K.P. and A.S.; writing—original draft preparation, J.K., K.B., M.P., K.P. and A.S.; writing—review and editing, J.K., K.B., M.P., K.P. and A.S.; visualization, J.K., K.B. and M.P.; supervision, J.K., K.B., M.P. and K.P.; project administration, J.K.; funding acquisition, J.K. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by Grant System of University of Zilina No. 12755/2021 "Testing of selected means of individual protection", No. 16963/2021"Research into the readiness of municipalities to deal with emergency events with an emphasis on the safety of the inhabitants" and KEGA 026ŽU-4/2020 "Innovation and internationalization of teaching as a tool to improve the quality of education at the FSI UNIZA".

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Acknowledgments: Publication of this article was supported by the Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic—VEGA No. 1/0628/22 "The Security Research in Municipalities with Emphasis on the Citizens' Quality of Life".

Conflicts of Interest: The authors declare no conflict of interest.

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International Journal of
Environmental Research and Public Health

MDPI

Article

Potential of Community Volunteers in Flood Early Warning Dissemination: A Case Study of Bangladesh

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Abstract: Flood early warning (FEW) is a vital component of disaster risk management and is particularly important for saving lives, developing a sustainable agro-based economy, economic stability, and the overall development of the people of Bangladesh as well as others. This study was conducted in a northern, flood-prone area of Bangladesh to investigate the potential of incorporating volunteers of the community to the Union Councils (UCs) to disseminate FEW alongside the top-down approach. Several studies have found that despite having a sophisticated flood forecasting technology, local communities are not reaping the benefits of it, as the existing dissemination system is inaccessible to most local people. Since risk communication takes place in a social context, this study investigated and thereby proposed that volunteerism, as a form of social capital or communal virtue, can potentially assist the community-based disaster management (CBDM) institutions in enhancing their capacity to reach the maximum population at times of flood risk. Therefore, it was confirmed that the trained volunteers need to be integrated into and endorsed by the national policy. In addition, this study also provides a number of recommendations connecting literature with policy documents of Bangladesh.

Keywords: flood early warning; flood response; community volunteerism; disaster volunteer group; resilience; governance and planning; disaster management; sustainability

Citation: Al-Mueed, M.; Chawdhery, M.R.A.; Harera, E.; Alhazmi, R.A.; Mobrad, A.M.; Althunayyan, S.M.; Al-Wathinani, A.M. Potential of Community Volunteers in Flood Early Warning Dissemination: A Case Study of Bangladesh. *Int. J. Environ. Res. Public Health* **2021**, *18*, 13010. https://doi.org/10.3390/ijerph182413010

Academic Editor: Paul B. Tchounwou

Received: 3 November 2021
Accepted: 3 December 2021
Published: 9 December 2021

1. Introduction

Flooding is a major natural disaster in Bangladesh, considering the number of people affected as well as the frequency of occurrence. Dissemination of flood risk information is an important part of a flood forecasting and early warning system (FFEWS) [1]. The government of Bangladesh strengthened the Community-Based Disaster Management (CBDM) approach based on the Union Councils (UCs), the lowest tier of local government institutions in the country. Under each UC there is a Union Disaster Management Committee (UDMC) responsible for managing disasters at the community level. However, it was realized that further improvement in the process of disseminating flood information was needed to reach those at immediate flood risk [2].The primary goal of a Flood Early Warning (FEW)system is to increase the safety of the people and reduce the harmful impact of floods [3,4]. People need to know the risk factors, and they should understand the warning to cope with the coming flood [5]. Therefore, a FEW minimizes risk to life, helps

to evacuate the danger zone in time, helps to move tangible valuable belongings to a safe place, encourages the taking of flood resilience measures, establishes two-way communication, and provides useful and expert advice. Despite these positive effects, several findings from contemporary studies have shown that individuals and households lack effective flood warnings at the community level in Bangladesh [6]. For an effective flood risk management timely warning, dissemination of flood information and response actions are essential for every community at risk. However, the communities of Bangladesh are not well aware of the FEWSs, and there exists a stark gap between the top-down national flood information flow and the intended recipients of that information. People prefer 'locally available and easily understandable' FEW and instructions at the community level of Bangladesh, especially those who are living at the union level (the lowest administrative unit of local government) [6]. Therefore, community participation in planning and implementing decisions of flood risk management needs to be institutionalized, a process which ultimately reduces vulnerability and builds disaster resilience throughout the community. The government of Bangladesh has indeed taken initiatives to institutionalize disaster management at the union level thorough UDMCs. However, the committees largely give importance to the post-flood relief, rescue, and rehabilitation process and less to disseminating FEW. It is not practical for the UDMC to reach all the villages and communities to disseminate a FEW. FEW information flows from the FFWC (Flood Forecasting and Warning Centre) to the union level. Figure 1 shows that FEWs are transferred directly to the target population and to the NGOs who are responsible for local disaster management [7]. It also indicates that NGOs disseminate information through their employees and volunteers to the target population, but no detail is given as to how NGOs and volunteers take part in this process. Considering this lapse, it is necessary to study the role of volunteers in disseminating FEWs in the context of a flood-prone area.

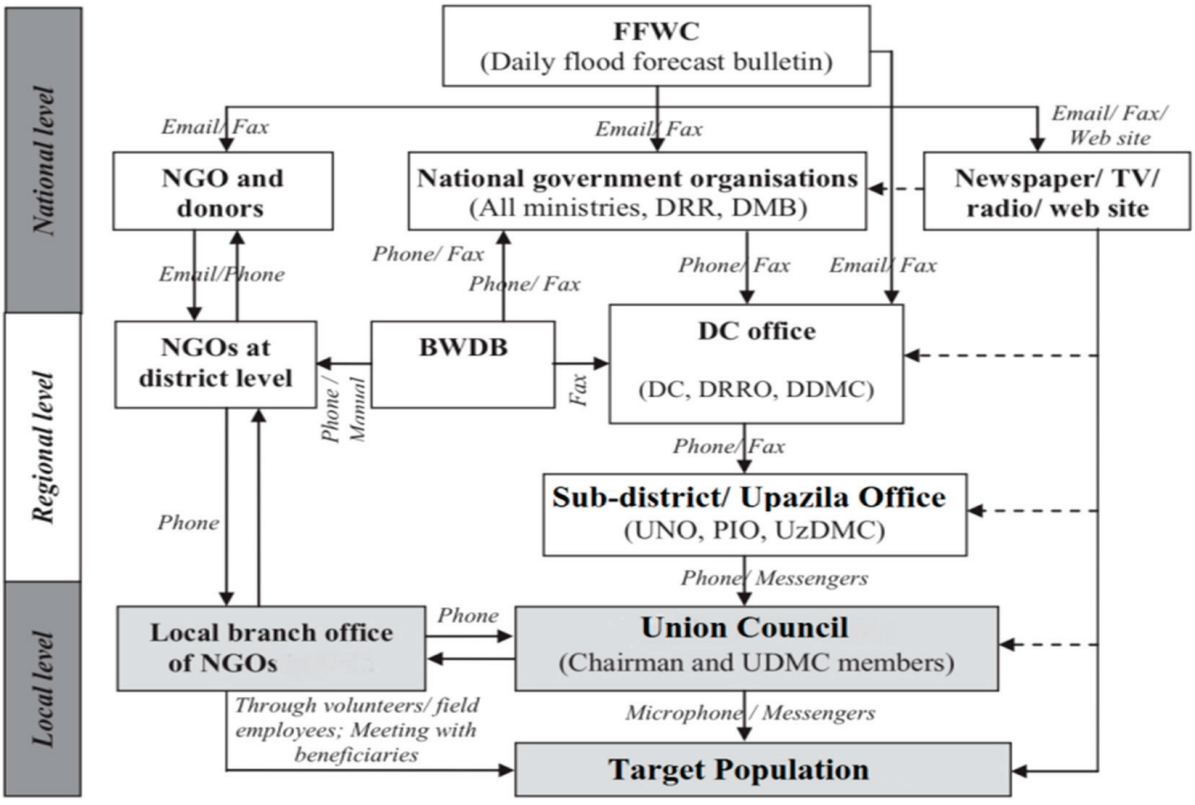

Figure 1. FEW dissemination networks from national to UC in Bangladesh (adopted from Shah et al. [7]).

Inevitably people's participation is required to improve the dissemination process; however, the role of community and neighbors proved to be very effective in a flood-prone area [2]. In connection to a FEW dissemination systems, the findings of a recent study in Azad Jammu and Kashmir, India, revealed that through the formal channels flood warnings did not reach 78 percent of the intended population, a distinct failure to address the needs of the community [8]. Both studies demonstrated that the active participation of the local community is critical to make a dissemination system successful. One of the reasons for failure of a FEW is that while designing the systems the advantages and disadvantages of different channels of FEW dissemination are not taken into account [9]. The most advanced and sophisticated technology does not necessarily lead to optimum outcomes. Furthermore, sufficient education and an uninterrupted electricity supply are important factors to access such technology. Mastor et al.'s [9] study noted the limitations of different channels used for a flood warning dissemination process and identified several disadvantages of technology-based dissemination systems, and these drawbacks very much correspond to the existing socio-economic structure of Bangladesh.

Technology is not a panacea for disaster FEWs [10]. In most developing countries, including Bangladesh, broadcast media, newspapers, and websites are used for the dissemination of flood risk information. However, these channels may not reach the at-risk population in a timely manner and/or provide sufficient information [11]. This technological inaccessibility cannot be solved in the short term, nor it is easy to make everyone aware of the warning system within a short period of time. However, it is possible to bridge the gap in terms of what is technologically available and what is socially available by drawing on social networks and strengthening the bond between official sources and local disaster risk management mechanisms. Volunteerism is a social capital, a common form of instinctive, often unplanned and uncoordinated assistance to help the community [12]. This quality of human behavior is one of the key elements that has significant potential to reduce disaster risk, build resilience, and generate immediate responses to a disaster [13]. Therefore, it is important to include the local community and volunteers when designing flood risk communication [14]. The idea of Community-Based Disaster Management (CBDM) opens a wide scope for individuals to work alongside the dedicated or responsible authorities in the disaster preparedness phase as well as in the response phase. In CBDM, volunteers can be widely incorporated into various activities. For example, in Sri Lanka, community volunteers are trained in hazard mapping, first aid, and building awareness, including trained 1000 volunteers from a community of 4,00,000 people to perform in an early warning system [15]. In Bangladesh, volunteers are also utilized in coastal areas for cyclone early warnings. A project named the Cyclone Preparedness Program trained 32,000 volunteers to disseminate cyclone early warnings [16]. Disaster preparedness involves understanding the nature of the hazard, planning, coordination, training, and leadership at every community, local, state, and national level of an existing decentralized government system, whereby creating and extending partnerships with volunteers have become increasingly urgent [17]. Participation of volunteers in flood forecasting exists in Central America, especially in Honduras, but the scope of using them in a FEW dissemination process has not been addressed in detail [2]. In a study on Community-Based Flood Early Warning Systems (CBFEWSs), the CBDM set-up in Nepal was found to be an effective mechanism in flood warning dissemination and response [18]. These CBDM committees comprise local media, the Red Cross, local police, military units, and forecasting stations of the Department of Hydrology and Meteorology. However, there is no involvement of the local resource of organized and unorganized volunteers in these committees. The only voluntary organization engaged in the committee is the International Federation of Red Cross (IFRC). However, the IFRC has a different definition of a CBEWS. For the IFRC, a CBEWS does not imply the participation of the community but merely refers to a system where any other organizations or agencies of the community implement the task on behalf of the community [19]. In the existing rich literature on FFEWS, there are other examples where volunteers contribute to the flood forecasting process, but none claimed the involvement

of local volunteers in the FEW dissemination, except the cloud-based FEWS (the latest version of technology based real-time FFEWS, participated in by individuals voluntarily using Google Drive's analytical features) [20]. However, this does not take place in a social context and unlike other 'pro-social actions' needs 'a planned action' and therefore cannot be considered as voluntarism [21]. Hence, therefore, a knowledge gap exists with regard to using the local resource of volunteers in the dissemination of a FEW.

Risk communication occurs in a social context, which allows information to pass through the responsible authorities to the intended recipients, not only with the help of technology but also through social interaction [22]. Social networks and social capital such as volunteerism can play a role in bridging the gap where technology fails to reach the maximum population. The principle of participation lies at heart of the CBDM [23]. There are numerous examples of volunteers participating in the diverse activities of government and business organizations [13,24]. The volunteers who are dedicated to disaster management are different from other forms of volunteers by virtue of different circumstances and their specific tasks [25]. This study explored the scope for volunteers in disaster management but in the preparedness phase—to be specific, in FEW dissemination processes [25,26]. However, the current study emphasized the positive aspect of this social phenomenon in an important and potentially disastrous issue such as a flood. Therefore, the current study concentrated on the pre-flood warning and information dissemination process, a topic which has gained less scholarly attention in studies on volunteerism. In this study, the existing role of community volunteers was investigated in the FEW dissemination process, the nature and extent of their relations with local government organizations in terms of top-down flood information flows, and the common perception of and potentials for incorporating volunteers into a community-based FEW dissemination system. To explore these issues, the following research questions (RQs)were investigated and answered:

RQ1. What is the role of volunteers in a FEW dissemination in the community level of flood-prone areas in Bangladesh?

RQ2.What is the relationship between local government institutions (in Bangladesh, Union Councils—UCs) and volunteers in terms of a FEW flow?

RQ3. How can volunteers increase the efficiency of UDMCs to disseminate a FEW in a community based flood management set-up?

2. Material and Methods

As this study explored how people in a specific social context make meaning, an inductive logic and qualitative method was employed [27].In the inductive approach, after collecting data, the authors developed themes which were used to identify patterns and theories. These themes or patterns were then tested and compared with the relevant literature.

2.1. Semi-Structured Interviews (SSI)

In this study, SSIs were used to collect information from participants who have had experience of floods along with volunteering. The reason for choosing an SSI is that they are flexible, accessible, intelligible, and efficient at disclosing important behavioral characteristics [27]. Moreover, an SSI allows opportunities to probe for further clarification to explore complex issues [28]. Each interview lasted for 20 to 30 min. To make the interviews consistent, an interview schedule was used (Supplementary Schedule S1). To make the interviews spontaneous, the interview schedule was not followed rigidly. The participants were allowed to speak their minds as much as they wished, and in fact were encouraged to do so. However, probing was often necessary to keep them engaged. Occasionally, a simplified alternative word was used to make the participants understand some technical words which were not clear to their native language of Bangla (in which the interviews were held), such as 'early warnings', 'volunteers', 'flood information', 'disaster management committees', among others. It was an important decision to make whether to conduct the interviews anonymously or overtly. While collecting data, hiding one's identity

is considered a less important ethical issue, but to some scholars it is a serious breach of ethical conduct [29]. Hence, a delicate combination of both was used here, i.e., a limited amount of information about the interviewer was provided. However, on occasions, the provided information gave a slightly different impression among the participants about the purpose of the research. In such cases, further clarification about the purpose of the study was provided.

2.2. Location of the Study and Sampling

The data for this study were collected from Ulipur (sub-district) of Kurigram District (Figure 2). Kurigram is a district of Bangladesh that has 18 different sized rivers entering from India and crisscrossing the land mass of all the sub-districts. Ulipur is a sub-district having a population density of 810/km^2 where floods constantly impact the local people [30]. It has three major rivers: the Brahmaputra, the Dhorola, and the Tista. These three mighty rivers cause floods almost every year to some extent [31]. Moreover, 50% of the area of Ulipur sub-district falls under the 'Tista Meander Floodplain Agroecological Zone', and it is known as a 'flood-prone' area with an average annual rainfall of about 2931 mm [32]. People here thus have a wealth of experience dealing with the floods and devising coping strategies. All the participants of this study were from different communities of Ulipur.

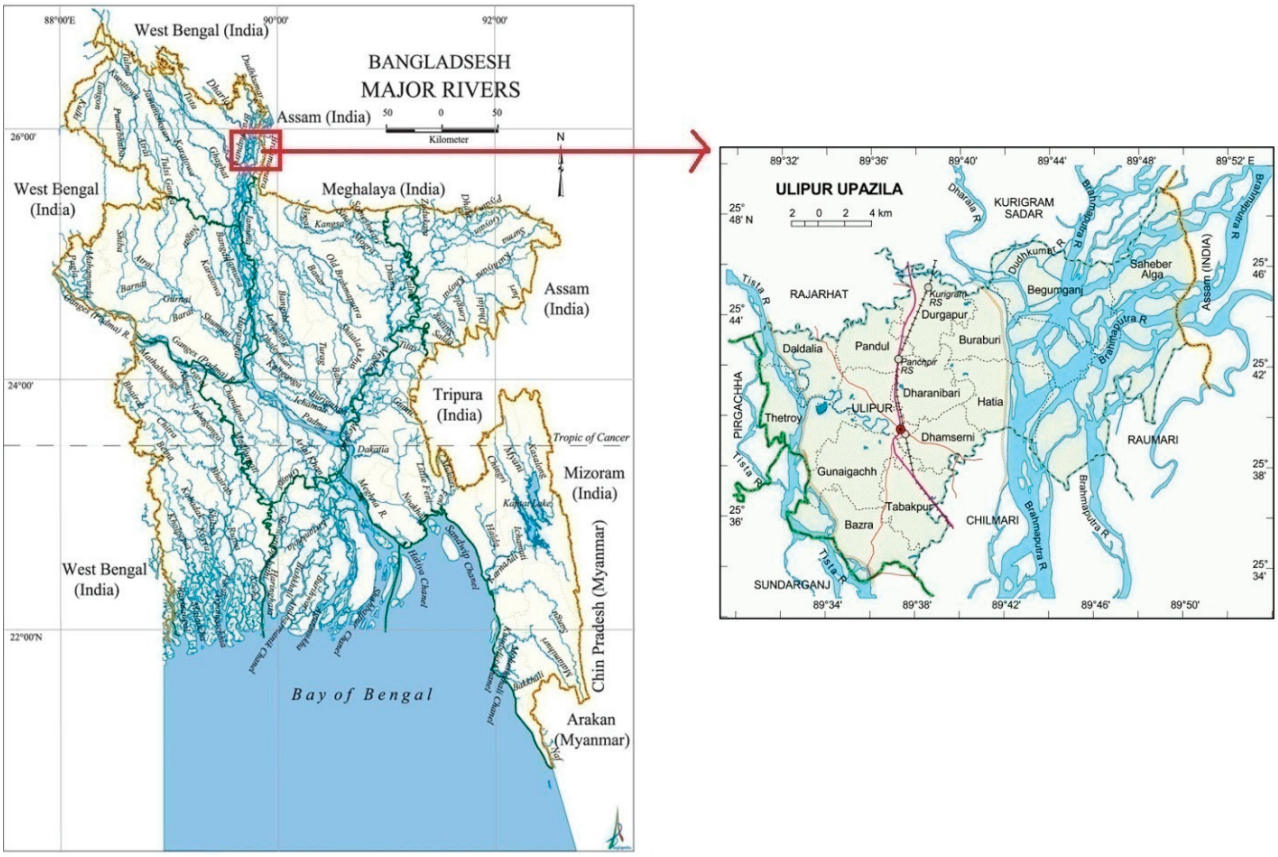

Figure 2. Hydrological system of Bangladesh and the location of the study area.

Considering the target of this study, a purposive sampling method was used to select the participants. Purposive sampling is a non-probability sampling strategy which is also known as judgmental, selective, or subjective sampling. Since proportionality was not the main concern of this study and subjective methods were included to decide the sample, this type of sampling was deemed appropriate [33]. Among the seven types of purposive sampling, expert sampling was used to select the participants because the interview questions may not have been suitable for non-experts. It is usual that many people do not

have an interest in disaster management, voluntarism, or local government institutions. Therefore, it was important to identify people with a particular type of knowledge and experience, such as local government institutes (UCs) of volunteerism and floods and who were willing to share it with the authors. The sample size was 10 participants, all residents of Ulipur sub-district. One of them was a government official, a member of the UzDMC, and the chief scout coordinator by designation. He was the first person to respond in the event of any emergency on behalf of the central government in a local government set up. Two participants were chairmen of two different UCs, who were solely responsible for managing administrative and development related activities in their jurisdiction. They were politically related to the wider population and elected directly by them. The next two participants were journalists who were well connected with the local government institutions and to the local populace. They also had experience in volunteering during emergencies alongside the administration. A further two participants were officially involved with a local level volunteer organization called Bangladesh Scouts. They were actively associated with the UzDMC but not with the UDMC and play an important role in post-disaster relief and rescue operations. The remaining three participants were local people with different occupations. They are vocal and widely seen as unofficial spokespeople in their communities. All the participants were permanent residents of different UC areas except the government officer. Since the nine participants were locals and had assets and permanent houses in this sub-district, they experienced varied levels of loss caused by floods over the years. All the participants willingly took part in this study. Before participating in the interview, the respondents were requested to acknowledge their consent verbally according to the consent form (Supplementary Schedule S2). They were also given opportunities to ask any relevant question regarding the purpose of the study. As this study deals only with the behavioral and perceptional issues of individuals, it did not pose any threat to the participants. To keep the recorded interview data secure, the audio files were encrypted, and only the authors had access to them.

2.3. Transcription

The recorded data for each interview were translated into English and transcribed immediately so that no comments were omitted and the meaning remained as intended. While the transcribing was undertaken with 'an appropriate level of detail', to reinforce the accuracy, the transcripts were checked several times [31]. The answers were organized according to each question asked to the participants. While transcribing, the identity (name and location) of the participant was not mentioned; instead, numbers (1 to 10) were used for the participants. All information that could reveal the identification of the participant was omitted from the interview files. However, some information about the participants' occupations was left, as it contributed to analyzing the data.

2.4. Data Analysis

To analyze the interview data, a thematic analytical approach was adopted. Importantly, while identifying the themes a semantic approach was adopted, meaning that the themes were identified according to the surface meaning of what the participants stated in their statements. The analysis of the data did not look for any 'inner meaning' or latent information embedded within the whole data set. In such an analytical process, the collected data is generally organized to describe patterns by describing, summarizing, and interpreting [34]. All transcribed data were uploaded in 'NVivo' software, and then the codes were marked within twelve primary themes, which were then gathered into four explicit themes, or main themes, until they represented meaningful patterns (Figure 3). This process followed the guidelines set out by Braun and Clarke [34]. Four themes were identified representing the underlying ideas of the participants. These themes described the present state of the local FEW dissemination processes, the role of volunteers in this process, the relation of the UCDMCs and the volunteers, and the scope for improvement in the FEW dissemination processes (Figure 3). It was noticeable that being isolated from

the context of the interview, these themes were no more related to the individuals' overall statement as a whole.

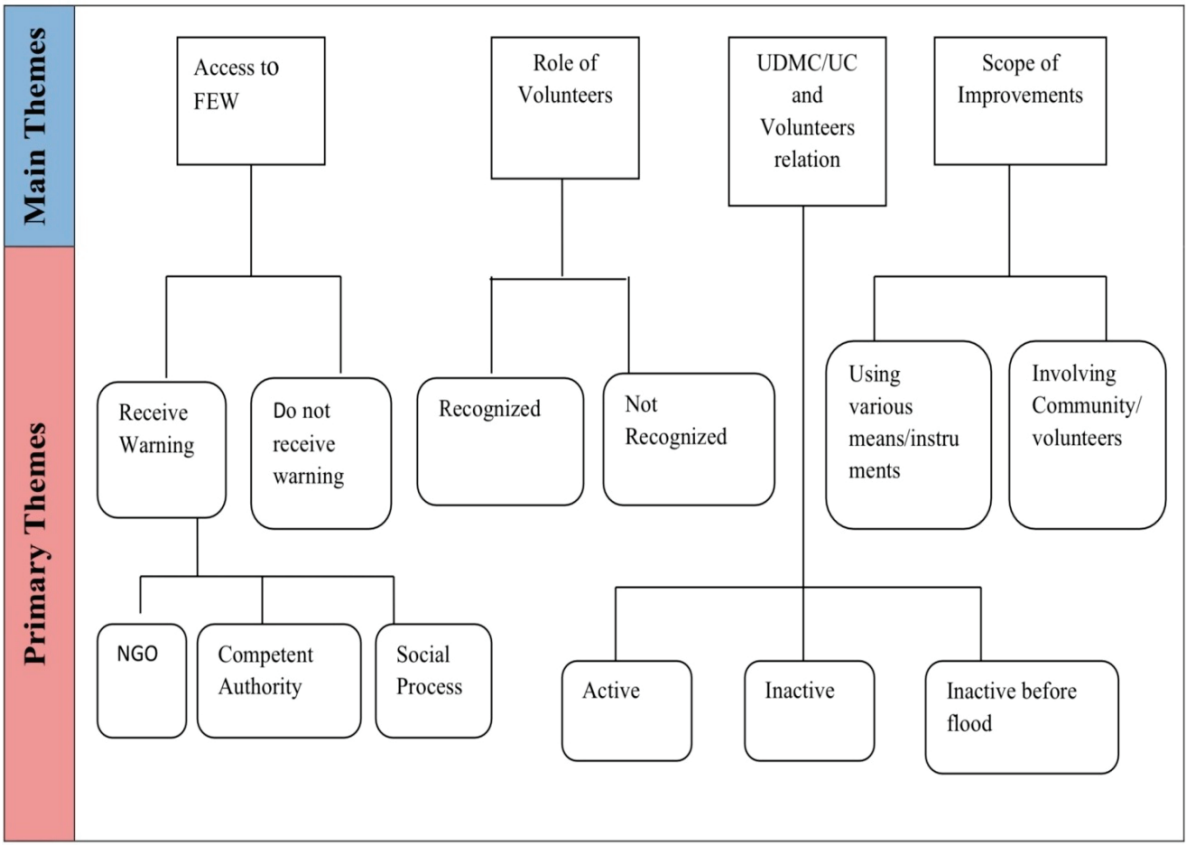

Figure 3. Schematic representation of the thematic map followed in this study to investigate the relationship of community volunteers with FEW.

3. Results

3.1. Access to FEW

Before discussing the contribution of volunteers in the flood warning dissemination process, it is important to ascertain whether people have access to flood warnings or not. People expect early warnings before any natural disaster. Therefore, the government and other agencies responsible for disaster management emphasize forecasting and warning. However, most of this study's participants did not acknowledge a FEW from any official sources. When asked how they receive flood warnings, one participant (No. 1) who had received a FEW replied as follows:

> We receive information of the water levels of the major rivers on a daily basis but during the rainy season we get hourly updates. Some of the information comes from the concerned ministries and the hydrological authority, some from the local leaders and some from locals living near the river banks. They send me information by email and fax, sometime I get phone calls. As I am directly related to the disaster management set up of this area, people keep sending me updates.

However, a majority of the participants said that they did not receive any FEWs. This theme had a number of additional findings. Two of the participants who agreed that they received some sort of FEW noted that this information came from informal sources such as relatives, local political leaders, and people they met in their leisure time. One participant (No. 4) said,

> We receive flood related information from various sources, for example local politicians or people living close to the rivers and remote villages. They are the first to inform us about the water level rise and estimated damage. But we do not get any information directly from the Upazila Disaster Management Committee or Union Councils. I have heard of some mobile messages but I think everyone do not get messages, never heard of people talking about receiving such messages.

One of these two participants (No. 8), who worked in farming and was well connected with local officials responsible for agriculture, said he received early warnings from a different kind of office unrelated to the state's flood forecasting and warning mechanism. Participants who did not get a FEW added that they use 'local knowledge' to predict the severity of a flood, although this knowledge is often not enough to give them sufficient time to save their crops.

Channeling an official FEW is a top-down information flow in Bangladesh. The concerned ministries and the hydrological authorities provide information to be broadcasted on TV and radio channels. However, a great number of participants said that they did not receive specific warnings through these channels. To some participants (Nos. 5, 8, and 9), this information was merely bad news, not a FEW. When asked about the function of TV, radio, and newspapers in disseminating a FEW, one of the participants (No. 10) stated the following:

The news we get from TV and radio channels is not useful. What use is a flood early warning when it is already going on? People need information at least 5 to 7 days earlier so they can save their assets and crops.

In addition, these FEWs are not specific to any particular area; they are mainly general information about the severity and losses caused by the flood. However, access to TV and newspapers was an important point. As one participant (No. 8), a farmer, said:

> I mainly get the overall flood situation of the country from TV but the agricultural extension office provides me with important instructions that are helpful for my farm. There is a problem with the TV; we do not get continuous electricity. Whenever there is a strong wind or rain starts, the TV signal is interrupted.

When asked, one participant (No. 4) had a different opinion of the effectiveness of TV:

> ... TV and radio news are enough to make people warned about the upcoming flood, but people do not realize the importance of these messages. That is why most of the time people are not adequately prepared.

Half of the participants considered TV bulletins less useful. One participant (No. 5) said the following:

> From TV and radio we come to know mostly about the areas where the flood has already hit. Sometimes there are programs where they tell us how to prepare before a flood, but we don't see them coming very often. Most of the time, we miss them because we remain busy in our daily work.

3.2. Role of Volunteers

This theme directly answered the RQ1. While most of the participants were of the opinion that volunteers were not involved in the FEW dissemination processes, a number of them acknowledged that they had shared flood-related information with their relatives and in the community when they came to know about an impending flood (Figure 4). The two participants (Nos. 6 and 7) who were members of Bangladesh Scouts did not recognize any role for volunteers in disseminating a FEW. One of them said,

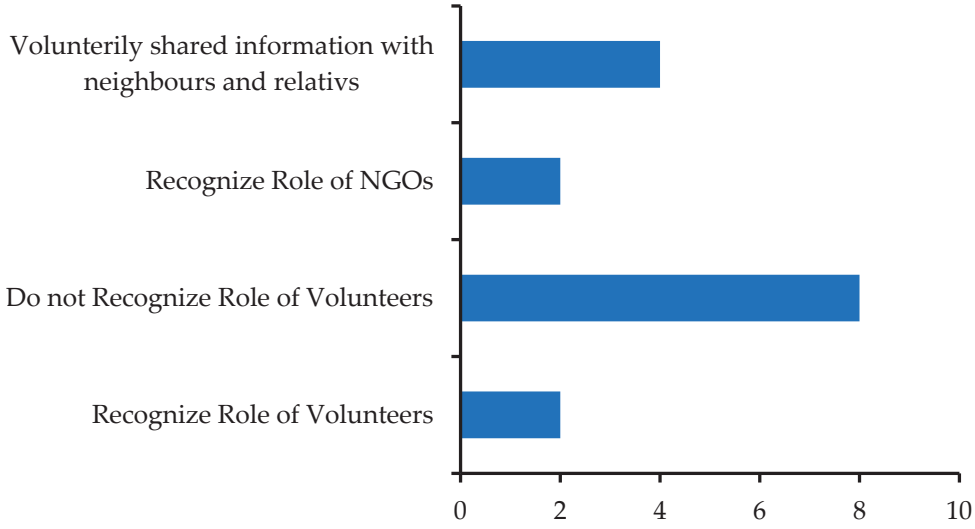

Figure 4. Recognizing the role of volunteers in FEW. Responses from the participants of this study.

> There is no specific volunteer group in our area working independently in a disaster situation. But we see NGOs who play a benevolent role before, during and after a flood. They warn people about the destruction of floods, arrange health training and provide relief to the poorest. They also take part in the rehabilitation process. We see Bangladesh Scouts and Red Cross taking part in the relief distribution. But none of them have any mentionable activities prior to a flood event.

In contrast, two participants (Nos. 1 and 3) recognized the role of volunteers in FEW dissemination. One of the participants (a member of a UDMC) noted,

> There are some volunteers who work to create awareness among school children. These volunteers are driven by some teachers who are involved with voluntary organizations. These types of activities are highly encouraging, but it is not a regular phenomenon.

However, further probing disclosed that when the participants (Nos. 8 and 9) came to know about heavy rain or flash floods in India, they started warning their family members and relatives, as there was a great possibility of that flood water hitting their lands. Yet they do not get such information very often.

As noted in Section 2.1, all the participants had some kind of experience in volunteering in their locality and were well-aware of their importance in emergency situations. They (Nos. 3,4,5,7, and 10) actively took part in post-flood situations. Still, they were hardly aware of disseminating FEWs and their role in it. When asked, one of the participants replied,

> I didn't realize it earlier. But I am not authorized to disseminate any flood-related warning to the people.

Another participant (No. 7) said,

> I can help if the government wants me to.

However, all the participants were of the opinion that they could play role in disseminating FEW if they were properly instructed from a competent government agency. While describing the role of volunteers, one participant (No. 1) mentioned that FEWs were sent to the UCs to take precautionary measures. The UCs held meetings and took the necessary action to disseminate FEWs. He said,

> We (UzDMC) pass required information and instructions to the UDMCs for wide circulation among the populace. These committees take initiatives to pass the

> information to the masses using microphones and other means . . . It is not well organized but UCs are solely responsible for that.

From this theme, public perception of the role of volunteers in a FEW dissemination can be identified. There are important findings about volunteers. First, there is no active role of volunteers in flood warning dissemination. Second, people spontaneously disseminate information that they have among their family members, relatives, and neighbors. Third, uncoordinated, some NGOs play a role in the flood information dissemination process. Fourth, the traditional top-down FEW system does not reach the mass of the population and does not use local people or volunteers. Five, people are willing to take part in the dissemination process, but they require a valid platform for doing so.

3.3. Relationship between the UDMC and Volunteers

To address RQ2, the participants were asked to state their understanding of the role of the UDMC prior to any flood event, the participation of local people, and how volunteers were connected with the UDMCs.

Seven of the participants did not recognize any action of the UDMCs before a flood event, but in contrast (and perhaps predictably), participants (Nos. 2 and 3) who were members of the UDMCs claimed the UDMCs were active before a flood event. One of them said the following:

> We have standing orders for UDMCs. There are clear instructions to arrange meetings in the UCs and plan for an upcoming disaster event. It is our responsibility to disseminate flood warnings among the populace although we don't know about any prescribed method for doing it. Within our limitations, when we get a FEW we try to disseminate the information using microphones and sending information to the remotest areas. Not every committee does the same. It depends on the decision of the committees.

However, other participants gave quite the opposite reaction:

> UDMCs are not very active. They are supposed to sit in a meeting every month but as far I know they only arrange meetings in emergencies. Most of the time, the main agenda is to formulate plans for relief distribution or recovery actions.

Another central concern of this study was to reveal the relation of the UDMC with the masses as well as the volunteers from the communities. In addition to the three participants who were member of the UzDMC, seven other participants claimed to have no direct involvement with the UDMCs:

> I do not have any direct contact with the UDMCs but I am informed about their activities very often. I communicate with the committee members to get updated information of the overall flood situation and the role of the government. I am not a part of the committee. But they ask for my help in the relief and rehabilitation process. I like to help the community people.

This participant claimed that the UDMCs have not yet developed any mechanisms to incorporate the pool of volunteers in any activities other than relief distribution and the subsequent rehabilitation process.

However, voluntary organizations such as Bangladesh Scouts and the IFRC take part in the UzDMC meetings. Different NGOs are also a part of this committee and their role is also limited to relief distribution and rehabilitation:

> Various NGOs and voluntary organization such as Bangladesh Scouts and the IFRC attend the UzDMC. They share their information and receive instructions. They usually prepare for relief and rescue operations but at the community level the participation of the volunteers is spontaneous. They are not organized; they just appear after the disaster and take part in the relief and rescues missions.

This theme had several findings related to RQ 2. First, the UDMCs were not sufficiently active before an impending flood. Second, community participation could help the UDMCs

to be more active in preparing for a flood event. Third, community volunteers had no links with the UDMCs. Fourth, although NGOs and other formal volunteer groups were involved with the UzDMC, their function was limited to the post-flood response phase.

3.4. Scope for Improvement

This theme addresses RQ3. It seems that all the participants realized the importance of an effective FEW system and had a positive view of it. In order to make the UDMCs more effective at disseminating an effective and holistic FEW, the participants expressed that the UDMCs have significant scope for improvement. One said,

> UDMCs are the last stage of the top-down disaster management process of the government. The success of flood management largely depends on these institutions. People reap benefits from the actions of these committees. That is why the accountability of these committees is an important factor. But they are hardly aware of the pre-flood measures that can decrease losses. Volunteers would be happy to get involved in such activities.

Not only increasing accountability and widening scope, participants also thought that the weakness of UDMCs could be reduced if community people would get a proper chance to contribute alongside the elected members of the union council:

> The UDMCs are weak at performing their duties. Though they have clear instructions, they hardly follow them. Very few people know about their activities. If other NGOs and local individuals can be involved in this committee, I think they can perform better.

When asked about the potential ways of disseminating a FEW to the maximum population, the participants agreed that mobile messages could be the easiest way. However, they also believed that this method would not reach the poorest and most uneducated sections of the community. Moreover, although many people use mobile phones today, there are still occasions when text messages may be missed. In addition, SMSs are too short to provide the requisite amount of detailed information. Furthermore, it is a one-way approach; people cannot get answers if they have any queries. One participant (No. 7) said,

> I think mobile messages can reach me quickly, but I may miss it. We get lots of SMSs daily. We do not pay too much attention to them. So, it is better to make arrangements for public announcements using microphones. In this way there will be little chance to miss the information.

Five of the participants emphasized the use of microphones in addition to SMS, and two mentioned local leaders and members of the UCs, the village police, and NGOs, while others held different opinions (Figure 5).

Although initially none of the participants spoke about any kind of social processes, they did begin to speak positively about employing volunteers and NGOs when probed. They also recognized the role of religious leaders (Imams) and teachers. Some suggested a 'door-to-door' approach:

> ... volunteers are good people. They are neutral and people have faith in them. They can go door-to-door because they know well who needs to be warned. If they use the microphones of the mosques and the UCs, it will cover maximum people; and people can also ask them questions if they have any.

However, few participants were not without doubts about the authority of volunteers to do this efficiently. They even thought that the existing nature of volunteerism was not capable of performing such actions:

> ... they can be good help but they are not well organized in our rural community and you cannot always get them around. We can make separate committees in our villages and train them. But who would believe them if they are not empowered by any competent authority?

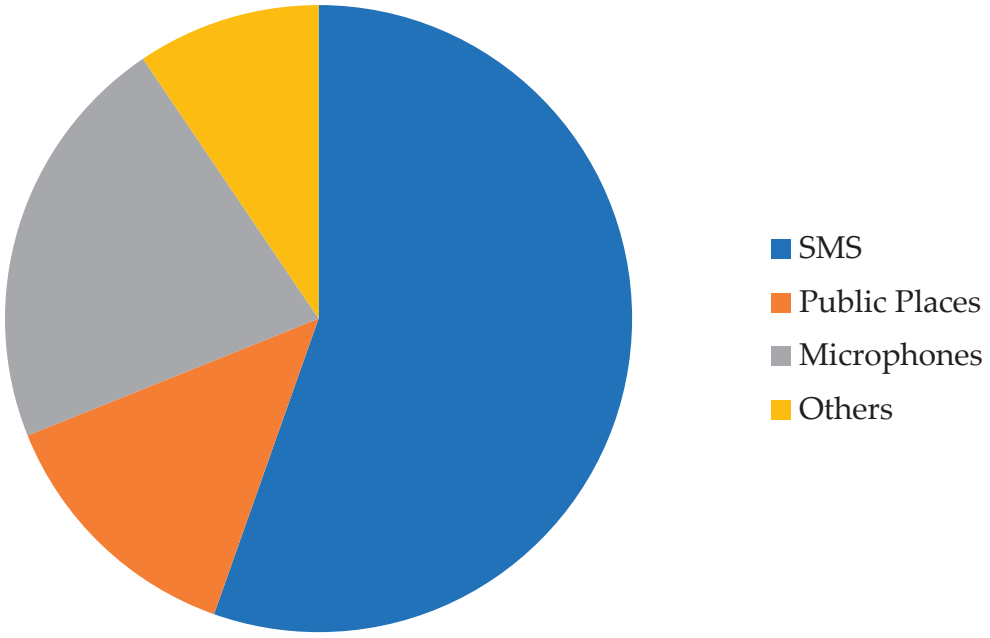

Figure 5. Expected means of communicating a FEW. Responses from the participants of this study.

In contrast, the members of both disaster management committees (UzDMC and UDMC) believed that volunteers have always been very helpful in implementing various government agendas and they could easily be organized in a single platform to assist the UCs in managing disasters.

In this work, four main themes were identified to answer the research questions. The first theme was not directly related to any of the three research questions, but it provided important information about the overall study. The second theme found that community volunteers did not take part in any pre flood preparedness activities, but they participated in the post-disaster response phase. The third theme identified that the UDMCs were not active enough, and that one of the reasons for this was that they did not involve community participation or volunteers in the pre-flood preparedness phase. The fourth theme suggested scope for how the FEW dissemination systems could be improved.

4. Discussion

In the preparedness phase of a flood, to be specific, in FEW dissemination processes, scant scholarly attention to the role of volunteers has been paid. Therefore, this study explored the social context of the community of a flood-prone area of Bangladesh and investigated the current state of its FEW dissemination system, the role of the volunteers in this processes, the relationship between the CBDM institutions and volunteers, and the scope for improvements that may be made by integrating local volunteers into the system. Connecting to the research questions, four themes were identified (Section 2.4; Figure 3), which are discussed below.

4.1. Access to a FEW

For an agro-based economy like Bangladesh, FEW is an important issue, as it increases the safety of millions of people and reduces damage to assets [3]. Therefore, access to FEWs is vital for people living in flood-prone areas. In this study, it was found that people living in a flood-prone community may not receive timely and effective FEWs through the traditional and technology based top-down channels. This finding is similar to the study performed by Fakhruddin and Ballio [6], where they studied the capacity and needs assessment of five flood-prone communities (sub-districts) in Bangladesh. In addition, this study found effective the roles of local communities and NGOs, local police forces, and agricultural extension offices in the flood information dissemination processes, which

also corresponds well with the outcomes reported by Fakhruddin and Ballio [6]. In local communities, locally managed and circulated flood information is preferred since they encounter issues accessing the technology-based means of FEWs [9]; therefore, it reassures the vital task to institutionalize community participation in the UCs to make UDMCs more efficient. Since community participation is a key resource in DRR [6], this study identified and explored sound grounds for involving community volunteers with UDMCs for progressive improvement of disseminating FEWs.

4.2. Role of Volunteers

The exploration of the role of volunteers in disseminating a FEW to answer RQ1 did not find a prominent role of volunteers prior to a flood event but did find this social behavior to be evident but limited to neighbors and relatives. In some cases, the voluntary contribution of teachers and local politicians was acknowledged, as was the contribution of NGOs. However, none of these actors are active enough to be formally defined as engaged in voluntary activity. This type of community-led flood warning dissemination was already acknowledged previously as an 'informal warning' [35]. However, this kind of informal warning process can raise problems such as authenticity issues, lack of information, and the possibility that false alarms are generated [9]. Moreover, communities lack sufficient technical knowledge to understand or update flood forecasting. Therefore, it is essential to combine these informal sources of flood warning with official channels [36]. The participants in this study fully realized the necessity of organizing community volunteers. The voluntary attitude of the local people can be amplified and reinforced by being institutionalized under the umbrella of UCs, which is hence recommended.

4.3. UDMC and Volunteer Relations

This study considered UCs as the spokespeople of the community. They are responsible for local disaster management through UDMCs. This investigation found that in the post-flood response and recovery phase, UDMCs are suddenly rendered very active supports, and volunteers work with and through them. Bangladesh Scouts and the IFRC actively take part in UzDMC meetings and engage themselves to offer help to the community although they do not collaborate with UDMCs, which are the center of the communities and the basis of Bangladesh's CBDM approach. From the participants' responses it was evident that although there is enough scope to include local people into UDMCs, as yet, this is not the case. However, it was found that UDMCs are too weak to support communities in a pre-flood situation. One of the reasons for this is that this macro-level local government body is not included in the list of organizations that receives flood bulletins from the FFWC of Bangladesh [2]. In the FEW dissemination model of Bangladesh, the UCs are related with local branch offices of NGOs, and NGOs take part in the dissemination process through their field employees and volunteers [7]. Furthermore, it needs to be ensured that the UCs have an appropriate and effective channel to receive FEWs through top-down approaches.

4.4. Scope for Improvement

This study found sufficient scope for improvement in the dissemination of flood warning messages. First, the inactive state of UDMCs needs to be addressed before an impending flood, allowing it to work as a common platform interlinking all social and administrative structures and organizations. Second, UDMCs need to create more scope for involving volunteers to formulate FEW messages and plan for and be intimately involved in their dissemination. Finally, UDMCs need to use various instruments considering the needs of the community. This study's participants recommended that volunteers use microphones and go door-to-door in at-risk areas to warn people. They also suggested that warning messages be delivered in public spaces such as markets or mosques; however, such improvements were also recommended previously.

The strengths of this study are two-fold: the identification of the geographical area; and the selection of the participants. Ulipur, as a study area, best represents the flood-

prone areas of Bangladesh and has a typical CBDRR mechanism that resembles other areas nationwide. The study's participants were also carefully chosen, including both flood victims as well as potential volunteers in an emergency situation who are also connected with community disaster management processes. The study's limitations are no less important. Firstly, if the number of the participants were larger, the results would have been more pragmatic. Secondly, it would have been more informative if this study had included participants who work in the policy formulation process of the central administration and disaster management board.

5. Conclusions

Though the role of volunteers is a nuanced topic, it has received less importance in the preparedness phase of disaster management, especially in terms of a FEW dissemination. Considering this, the current study focused on the perception of incorporating volunteers prior to an impending flood event and revealed that the perceptions of the would-be volunteers are very strong and positive in connection to the flood risk communication. Further, it was also observed that active inclusion of volunteers in the UDMCs needs to be practiced in the form of a dedicated national disaster volunteer group, which is already prescribed in the national policy document, however yet to be implemented. Nevertheless, it would be imperative to train volunteers of flood-prone communities for enhanced flood risk communication. Moreover, further research is needed in the dissemination endeavor. Finally, this study verified the necessity of granting a legal door to volunteers to establish a dedicated national disaster volunteer group effective for all sorts of emergencies.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/ijerph182413010/s1.

Author Contributions: Conceptualization, visualization, resources, and data collection and analysis, M.A.-M.; writing—original draft preparation, M.A.-M.; editing, proofreading, and finalizing, M.A.-M., M.R.A.C., E.H., R.A.A., A.M.M., S.M.A., A.M.A.-W. All authors have read and agreed to the published version of the manuscript.

Funding: This study is an outcome of an MSc degree, which was funded by the 'Strengthening Government through Capacity Development of the BCS Cadre Officials' Project implemented by the Ministry of Public Administration, Govt. of Bangladesh, through a scholarship awarded to M.A.M. for the academic program at the University of Manchester, UK.

Institutional Review Board Statement: All subjects gave their informed consent for inclusion before they participated in the study. The study was conducted according to the guidelines of the Declaration of Helsinki, and through the approval of the Ministry of Public Administration, Dhaka, Bangladesh (Ref: 05.00.0000.138.05.001.15-463).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: All processed data were presented and described in Section 3 (Results). However, the data that support the findings of this study are not publicly available because we did not ask participants to consent to raw data sharing outside of the research team. Public sharing of the data could compromise anonymity and research participant consent.

Acknowledgments: The assistance of Ayham Fattoum, University of Manchester, UK, to design and prepare the MSc dissertation is gratefully acknowledged. The authors extend their appreciation to the Deanship of Scientific Research at King Saud University for funding this work through Research Group no. RG-1440-134.

Conflicts of Interest: The authors declare no conflict of interest.

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International Journal of
Environmental Research and Public Health

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Article

A Conceptual Design of Smart Management System for Flooding Disaster

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Abstract: Disasters pose a real threat to the lives and property of citizens; therefore, it is necessary to reduce their impact to the minimum possible. In order to achieve this goal, a framework for enhancing the current disaster management system was proposed, called the smart disaster management system. The smart aspect of this system is due to the application of the principles of information and communication technology, especially the Internet of Things. All participants and activities of the proposed system were clarified by preparing a conceptual design by using The Unified Modeling Language diagrams. This effort was made to overcome the lack of citizens' readiness towards the use of information and communication technology as well as increase their readiness towards disasters. This study aims to develop conceptual design that can facilitate in development of smart management system for flooding disaster. This will assist in the design process of the Internet of Things systems in this regard.

Keywords: information and communication technology; smart disaster management system; Internet of Things; flood; disaster

Citation: Ibrahim, T.; Mishra, A. A Conceptual Design of Smart Management System for Flooding Disaster. *Int. J. Environ. Res. Public Health* **2021**, *18*, 8632. https://doi.org/10.3390/ijerph18168632

Academic Editors: Mariusz Goniewicz and Paul B. Tchounwou

Received: 27 May 2021
Accepted: 9 August 2021
Published: 16 August 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

1. Introduction

A disaster is an abnormal event that local capabilities cannot control and requires national or international assistance [1]. Disasters can be classified into two types: natural disaster and man-made disaster [2]. Flood is one of the natural disasters caused by the high level of fresh water or salt water [3]. Natural disasters have a huge negative impact on people's lives and property by killing, injuring, and displacing people. Floods were among the most common natural disasters in the last decade, reaching about 50% of the natural disasters rate [4]. Due to damages caused by disasters, many private sectors and public organizations have tried to develop policies, frameworks, and systems for coping with future disasters by addressing these disasters in a scientific and deliberate manner [5]. Additionally, the necessary plans should be prepared in advance before the disaster strikes; this procedure is called a disaster management system (DMS) [6]. Natural disasters can be defined as a group of violent natural activities that occur suddenly in populated areas, causing heavy casualties and preventing people from taking precautions to mitigate their destructive effects [7]. One of the most important responsibilities of any government is to protect its citizens and national resources from any threats, especially natural disasters. In addition, one of the main services provided by the government to its citizens is security, which is defined as preserving the life and property of citizens from damage, whether due to humans or the surrounding environment [8].

The smart disaster management system (SDMS) is a DMS modified by the addition of information and communication technology (ICT) [9]. This system takes advantage of the facilities provided by ICT to accelerate the delivery of information and reduce the rate of error in decision-making in the event of a disaster. The intelligence of this

system comes from its ability to both collect information related to the disaster and make decisions in real time [10]. The motivation behind the design of an SDMS is to increase the readiness of people to use ICT in a correct and efficient manner. In addition, it aims to increase the citizens' reliability on E-government applications by enhancing the utility of these applications. Another important aim is increasing the citizens' readiness for disaster management through facilitating the ways of communication between people and the SDMS.

Flooding is the failure of the waterway to absorb rainwater to exceed its natural course and inundate the surrounding areas [11]. Flood can be addressed as one of these natural disasters. The continuous suffering of mankind from the impact of flood disaster over time was the main motivation for the development of this research. The International Federation of Red Cross and Red Crescent Societies (IFRCS) estimated that between 2008 and 2017 about 8.6 million people were displaced because of disasters (flooding). Over the last decade of the twentieth century, floods have influenced some 1.5 billion individuals. Around 200 million people worldwide live-in coastal areas prone to flooding [12].

Floods more often than not are the result of extreme and consistent precipitation that surpasses the absorptive capacity of the soil and the draining capacity of streams and rivers, especially in coastal regions. Thunderstorms, tornadoes, tropical cyclones, monsoons, melting ice and dams could cause flooding as well. The foremost types of floods are flash flooding, snow-melting surges, coastal flooding, and waterway flooding. Sudden flash surges are the most perilous since they happen unexpectedly, particularly at night [13].

Increased population density, fast and poorly planned urbanization, such as destruction of timberlands and natural confinement zones that prevent destructive floods, and climate alteration are all major factors of floods. As these processes are increasing, more individuals will be exposed to future floods. Dissolving ice sheets and rising ocean levels will cause flooding in areas that had not been exposed to surge hazards. Developing countries are at the greatest risk, and although Asia remains the worst continent hit by surges, Africa and Latin America have been affected more frequently in recent years. It should be emphasized that wealthy nations are not safe from the threats of flooding.

Flood disaster is one of the most frequent natural disasters that occur all around the globe [14]. Based on a research conducted by Institute of Environmental Studies, more than 60% of world cities be vulnerable to flooding in next 30 years due to climate changes effects and it will also lead to sea-level rise [15]. In 2014, natural disasters caused 7700 fatalities and losses of USD110 billion worldwide [16]. Flood occurring is the common disaster among all disaster [17]. In Australia, flooding accounts for an average of USD377 million in damages annually [18]. Applying and integrating sensory information in disaster management has gained attention in recent years as an efficient solution for providing live disaster information [19,20]. The application of sensors to measure the hydrological data and transmission over network has become common in many countries; presently, the Internet of Things (IoT) has been focused to improve disaster management on flood [14]. Therefore, this study pursues further advances in this regard.

2. Background and Related Work

The main aim of this study is to provide a conceptual design to advance in the development of a smart management system for flooding disaster. According to the World Meteorological Organization (WMO), flooding remains the third biggest disaster in the world [21]. Presently, IoT has become one of the technologies that has been used as a study to improve the area of disaster management focusing on flood [14]. They provided a review on application of IoT for flood data management and proposed an IoT architecture in this regard. IoT can be used to monitor the environment such as water level, flow rate, rainfall, and many other things. Thus, there are many early warning disaster systems integrated with IoT [22]. Inputs to flood forecasting system include many hydrological, meteorological, and geological data collected from an extensive network of monitoring stations. The data

includes river level and river flow, rainfall and tide, and these data originate from various devices [23]. Based on the result of experiments conducted, the flood early warning system worked properly as observed by the accuracy of the prototype achieved, which has a 95.6% accuracy [22]. Rismayana et al. (2018) [24] proposed a prototype system of flooding early warning system using IoT and social media. Their system serves to measure the water level at any time and send data in real time to the server and communicates the warning message to all registered telegram contacts. Ji and Anwen [25] proposed an application framework of IoT in an emergency management system in China. Chen et al. (2013) [26] developed an IoT application for safe buildings, where this application focused on helping people escape from the buildings in case there is a fire or an earthquake. Mitra et al. (2016) [27] proposed an IoT and machine learning-based embedded system to predict the probability of floods in a river basin. An IoT-based water monitoring system that measures the water level was proposed by Perumal et al. (2015) [28]. Mane et al. (2015) [29] developed a flood forecasting system using data mining and a wireless sensor network. Du and Zhu (2012) [30] investigated the application of IoT technologies in monitoring, controlling real-time data, and accurate prediction of early warning for urban public safety emergency management.

Ghapar et al. (2013) [14] reviewed research works that utilize IoT for flood data management and proposed an IoT architecture for flood data management that can facilitate for IoT infrastructure implementation. Kumar et al. (2019) [31] explored the research challenges of designing an information framework that couples physical sensors with the social sensors to collect heterogeneous flooding disaster data, and then to fuse that data and generate actionable understandings. The goal was to improve the response preparedness of critical infrastructures, contributing to the goals of smart and connected communities [32]. Data from sensors can be used for developing early warning processes towards useful early warning for flood management. Prevailing experience indicates that several devices have been developed based on sensor data and integrated satellite such as TRMM rainfall, Radar sat SAR, and Namibia Flood Sensor Web [32]. Therefore, this study will facilitate in developing a conceptual design of (SDMS) for flood warning. The rest of the paper is structured as follows: Section 3 presents the literature review. Section 4 describes the methodology. Section 5 provides the discussion. Finally, Section 6 includes the conclusion, limitations, and future work.

3. Literature Review

In the field of flooding and aquatic monitoring. Table 1. below shows the recent studies along with the main themes of these studies:

Table 1. Recent studies with their contribution.

Wellington J, et al. (2017) [33]	Observed a lack of focus on the technical aspects of IoT technology. Argued that sensor networks, IoT, and embedded system structures can be used for the smart networks for emergency handling.
Rafi et al. (2018) [34]	Concluded an effective response to a disaster requires fast flow of information and integrated response activities; thus, computing technology can be helpful in this regard.
Shalini, et al. (2016) [35]	Designed a system to measure the level of water in the river using special sensors to measure water levels as the distance from the bottom of the river and send the data to the monitoring center using Wi-Fi technology, the information sent via smartphones using GSM technology to the decision-makers.
Organization of American States Disasters (OAS) (1990) [36]	Defined the (DMS) to harness the full potential of governmental and non-governmental institutions in the event of a disaster in order to minimize the damage caused by the latter.

Table 1. *Cont.*

K. Yao (2015) [37]	Provided another definition to the DMS, which is the system that is used to manage disaster-related data by using information technology (IT), which combines geographical information with administration information to facilitate access to and use of these data in all disaster stages.
Eraslan et al. (2004) [38]	Tried to change the administrative structure of the DMS by proposing the use of the communications side of (IoT) to connect all parts of the system with each other and make them work as one integrated unit. Then, they suggested the establishment of a central control unit that communicate with all other units of DMS using IoT.

Disaster management can be divided into three stages [39]:

3.1. Before Disaster

In this stage, the disaster management team has the following duties:

Take all the necessary preventive measures, both administrative and executive, to save the lives and property of citizens and minimize losses to the lowest possible rate.

Review all studies on disaster risk reduction and take into account all proposals referred to in these studies.

Stay alert in the event of a disaster to ensure prompt and effective action.

Raise awareness among the citizens and create a well-informed society in order to obtain their assistance in the event of disasters, thus reducing the damage to a minimum.

3.2. During Disaster

This is the most critical stage for the disaster management team because of the chaos caused by the disaster; therefore, the team has deferent responsibilities, such as [40]:

Provide decision-makers with real-time data about the disaster, people affected, and the physical damage.

Saving as many afflicted citizens as possible.

Coordinate with government institutions, civil society organizations, and citizens trained in first aid to maximize their efforts in rescuing citizens.

Act directly to rescue people injured or trapped under rubble.

3.3. After Disaster

At this stage, the disaster management team has the following duties:

Provide suitable shelters for citizens who have lost their homes.

Provide affected people with the necessary needs for daily life, such as food and medicine.

Provide material and moral compensation to citizens who suffered losses during the disaster.

4. Methodology

In order to enhance the (DMS), a conceptual design was developed by supposing a disaster scenario; this scenario must be visualized by:

a. Defining the system requirements.
b. Using a use case diagram approach to visualize the role of participants.
c. Using a class diagram approach to visualize the system activities.

Therefore, a scenario will be prepared for each stage to explain the activities and responsibilities of each person within the system. The system stages are explained as follows:

1. Before Flood Disaster Stage

This stage is the pre-disaster stage and includes all the physical and psychological preparations needed in case a flood disaster strikes; the scenario of this stage is as follows:

a. System requirements
    1. PCs, sensors, networks, data centers, database (DB), and Internet service.
    2. Smart devices containing Global Positioning System (GPS) software.
    3. The alarming system connected to AI software.
    4. The training center containing all training requirements to train citizens and disaster teams.
    5. Food, medicines, and equipment to be used during and after the disaster.

b. People
    1. Disaster Management Team
        - Team leader: this person is responsible for declaring a state of emergency in the event of a disaster and has the authority to issue instructions to the disaster management and support teams as well as volunteers. This person is also responsible for the management of disaster from the moment of its occurrence until the last stage. Therefore, this person must have administrative authority, such as being a governor or the city mayor.
        - Team members: as members of the disaster management team, they are experienced in dealing with all types of disasters and have sufficient skills to train volunteers and control any emergency during a disaster. Members of the team must always be in a state of readiness for disasters.
    2. Supporting

Supporting staff are non-permanent members of the disaster management team, but when a disaster occurs, they are on alert to help the disaster management team. In addition, they must be skilled in dealing with emergencies. These are:

- Police officers: police officers have an important role in the event of disasters, as they have experience in first aid and various other ways to deal with emergencies. In addition, they can protect important facilities from tampering and theft.
- Firefighters: the main role of firefighters is to put out the fires caused by the disaster; they are also essential in rescuing people trapped in the rubble because of the collapse of buildings. They also have experience in first aid.
- Paramedics: the primary duty of paramedics is to provide first aid to injured people and transfer serious cases to the hospital in the event of disasters.
- Transporters: transporters evacuate people affected by the disaster to safe areas in order to preserve their lives. In addition, they must also be able to provide first aid during the disaster.
- Volunteers: volunteers are civilians who have been trained by the disaster management teams on first aid, therefore, they are useful during disasters to save people and minimize casualties.

c. Use Case Diagram

Use case diagrams for the stage before disaster were used based on the advice of the Thesis Monitoring Committee and the recommendations of the system developers. The purpose of using these diagrams is to illustrate the roles of people involved, processes, and data flow within the system. Figure 1 shows a diagram for the stage before disaster in the proposed SDMS.

1. The team leader is responsible for determining the training plan, its dates, the participants, and the necessary materials.
2. All SDMS team, including the team leader, will participate in the training program in order to be ready to deal with the disaster.
3. Technicians are responsible for installing the system hardware, connecting, and testing the network and conducting periodic checks on all parts to ensure it is working properly.

4. Sensors start sending their data to the data center to check the monitored area for any abnormal situation.
5. The data center will receive data and analyze it; if any abnormal pattern is detected, the system will compare the abnormal data with the historical data stored in the DB.
6. If the system decides that there is danger, an alarm message will be sent to the team leader.
7. The team leader will determine the risk ratio according to the data received from the data center.
8. If the situation is controllable, the team leader will send the specialists to control the situation and send their report to the DB to be saved as historical data.
9. If the level of risk is high, the team leader will declare an emergency and start the second phase of the system.

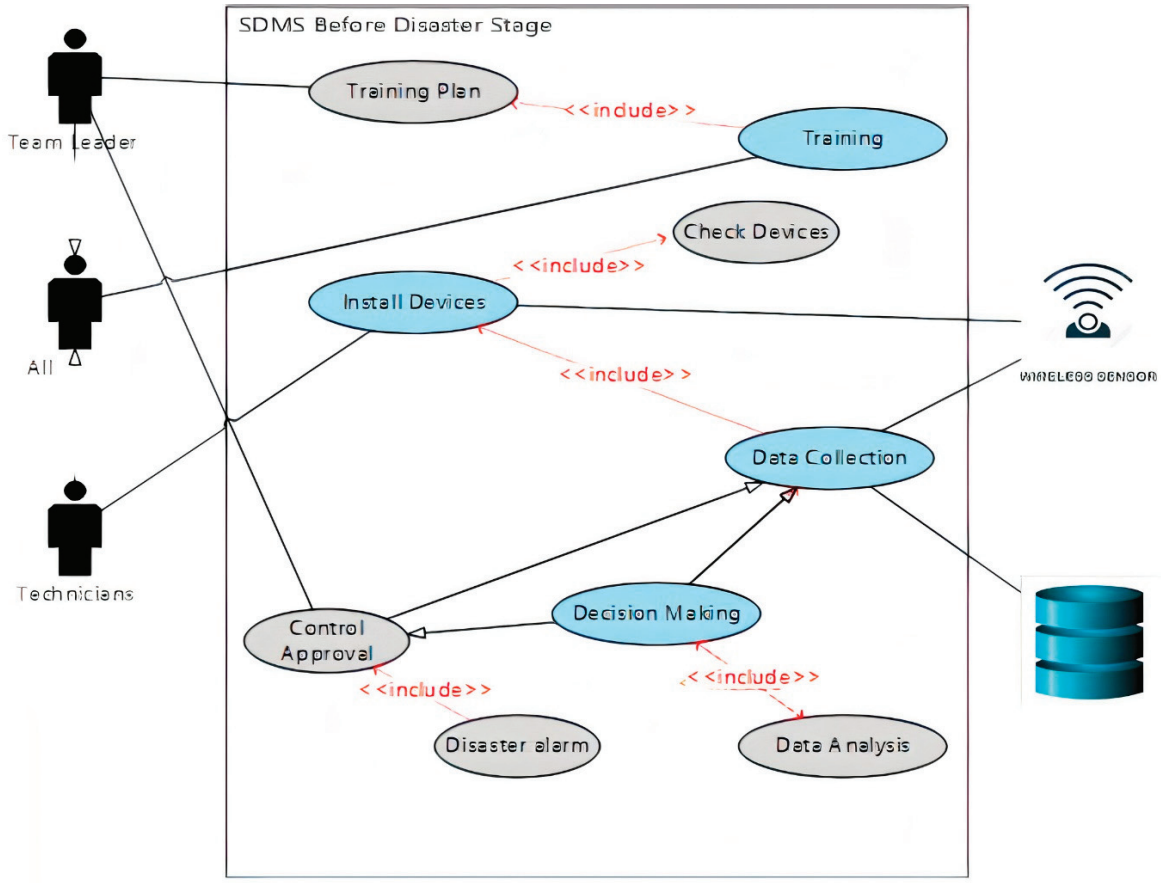

Figure 1. Use case diagram of before disaster stage [39].

d. Flooding scenario
    1. The team leader sends an alarm message to the team members, supporting teams, and civilian volunteers, ordering them to start the flooding disaster plan.
    2. The first step in the flooding disaster plan is warning people of flood disaster by using all communication methods such as SMSs, social media, TV channels, and radios and encouraging them to go to the safe zone.
    3. Use radio-frequency identification (RFID) technology to detect the location of the elderly and the disabled in order to save them.
    4. Evacuate people and transport them to safe areas that have been prepared during the preparatory phase of the disaster.

5. Cut off electricity, gas, and water sources to avoid any additional damage caused by them.
6. Use rescue boats to save people at risk of drowning and recover bodies.
7. Use water suction pumps to reduce the water pressure from the affected areas.
8. Use loaders and lorries to make earth mounds that keep floodwaters in control.
9. Use RFID to detect trapped people and save them.
10. Provide first aid to people affected with minor injuries.
11. Transport people who are seriously injured to the hospital.
12. Keep the team leader informed about the latest updates of the disaster and the real situation on the ground.

2. During Flood Disaster Stage

This is the most dangerous and important stage for the SDMS. During this stage, events are handled in real time and the disaster management team must be adequately trained and equipped to deal with the situation. Successful management of this stage significantly reduces the loss of life and property.

The addition of ICTs to the DMS will significantly improve the performance of the system. GPS and IoT can be used to transmit information in real time and controlling many devices remotely can be an important factor in the success of disaster management and control at this stage. The scenario of this stage is as follows:

a. Requirements
    1. Cell phones, smart devices, PCs, satellite channels, and internet service.
    2. Buses, ambulances, fire vehicles, police cars, fire fighting aircraft, rescue boats, lifeboats, loaders, and lorries.
    3. Sensors, RFIDs, wireless communication devices.
    4. Electric generators, water suction pumps, masks, respirators, and fire extinguishers.
b. People
    1. Disaster management team (team leader, team members)
    2. Supporting (police officers, firefighters, pilots (to drive firefighting aircraft), divers (to search for sunken people), paramedics, transporters, volunteers).
c. Responsibilities

In Figure 2, it can be seen that the SDMS system plays a central role, as it announces the occurrence of the disaster. It also manages all real-time data received in the database during the disaster. It also cuts off energy sources (electricity and fuel) automatically while the leader and members of the disaster management team are busy with their work. In addition, it locates victims and stranded people using GPS technology. All these properties are not found in the tradetional systems.

The figure also shows the role of the team leader (who is also considered a member of the team) as he/she supervises the team members and participates in all the activities carried out by the team in which the system has no role. The role of the team leader does not end, even after the disaster ends, as the team leader begins to manage the post-disaster phase and then prepares for upcoming disasters by training the team and preparing logistical support. As for the team members, their responsibilities vary according to their positions; some of them carry out the evacuation process, some drain the water, and some carry out the process of rescuing the injured and providing first aid to them, since in the disaster stage all citizens are considered members of the disaster management team.

Figure 2 shows the flowchart of main disaster stage activities. When the system receives real-time data that contains an emergency case or abnormal data related to the flooding, it directly informs the decision-makers or disaster team leader to confirm the disaster mode in order to start the disaster management procedures by mobilizing all team members as well as the volunteers. The SDMS will work in parallel with the disaster team depending on real-time data received from IoT sensors to cut off all power resources to avoid any fire or electricity danger.

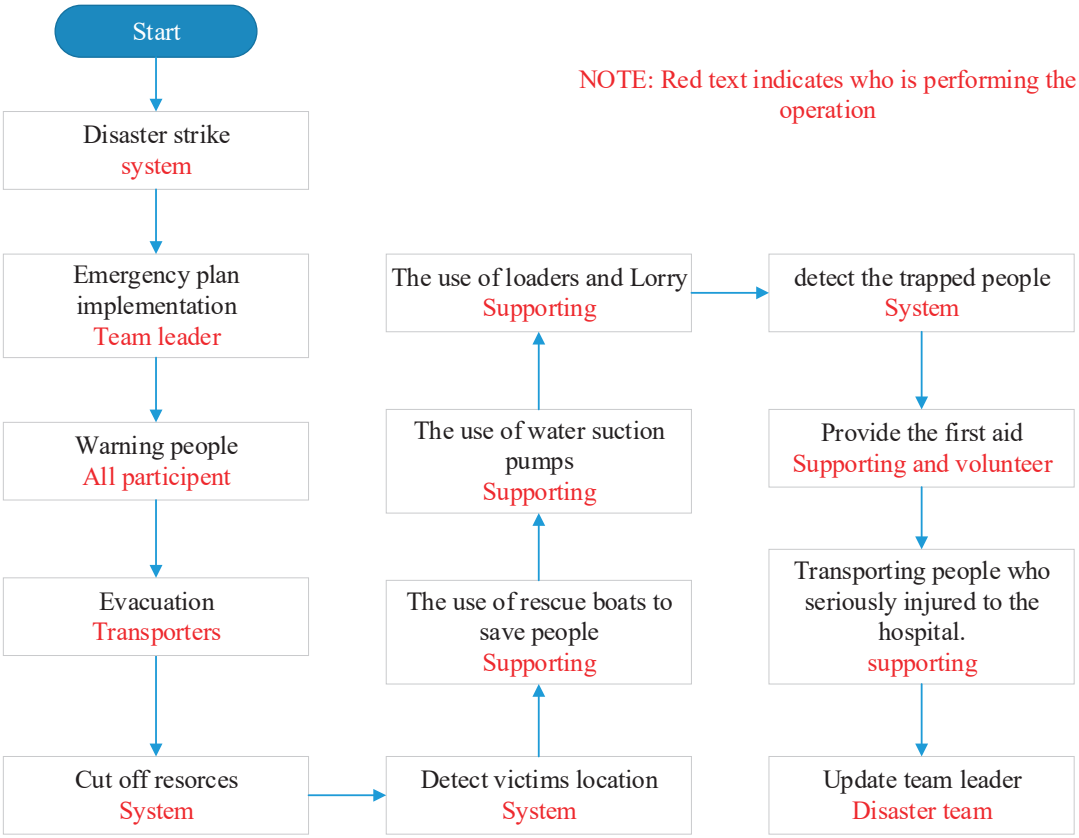

Figure 2. Flowchart of detailed activities of flooding during disaster stage [39].

The team will start the evacuation function with the help of the system to detect the victim's location in order to provide the first aid to them or transport them to the hospital if their situation is so critical. The earlier works are carried out in conjunction with an attempt to reduce or control the water level to prevent the increase in the impact of the flood. Due to the advent of ICT applications, IoT sensors instruct controllers installed in electronic gates to open those gates in order to drain larger amounts of water to reduce the impact of flooding.

When the dangerous situation is over and the water returns to its normal level, the system will update the situation and move to the post-disaster stage. The team will begin repairing the damages, in addition to providing camps, medicine, and food for displaced people. When everything is returned back to normal, the team leader will announce the end of the disaster and return to standby mode.

d. Use case diagram of during the disaster stage

The use case diagrams for the period during the disaster stage were designed according to the recommendations of the system developers. The purpose of using the use case diagram is to illustrate the roles of people, processes, and data flow within the system. This stage includes two diagrams: one for the main activities of this stage, and one for the special cases of flood disaster. Figure 3 below shows the use case diagram during the disaster stage of SDMS.

1. The team leader is responsible for announcing the disaster and approving the use of the emergency plan.
2. All SDMS teams will start warning people about the disaster.
3. The transporters who are part of supporting team will evacuate people to the safe zone.
4. The supporting team and the system will cut off the electricity, gas, and water to prevent additional damage.

5. The supporting team will deal with the special cases which will be explained in detail later.
6. The volunteer team will provide the first aid to injured people who are not in critical conditions.
7. Ambulances from the supporting team will transfer the critical cases to the hospital.

Figure 3. Use case diagram of during disaster stage [39].

3. After Disaster Stage

This is the last stage in the SDMS, at the end of which the system will return to standby mode. During this stage, the disaster management team, supporting team, and civilian volunteers have different duties in different scenarios, which is as follows:

a. Requirements
   1. Cell phones, smart devices, PCs, DB, Internet service, RFID, and statistics software.
   2. Tents, food, clean water, and medicine.
   3. Trucks, ambulances, police cars, generators, water treatment plants.
   4. Building materials.

b. People
   1. Disaster management team (team leader, team members)
   2. Supporting (police officers, paramedics, statistics experts, technicians, construction workers, transporters)
   3. Volunteers

c. Use case diagram of after disaster stage

The purpose of using such diagrams is to illustrate the roles of people, processes, and data flow within the system. Figure 4 below shows the use case diagram for the after-disaster stage.

1. Statisticians as a support team with the help of SDMS will conduct statistical analyses to determine the number of surviving, injured, missing, and dead people, in addition to identifying material losses and damage to infrastructure.
2. Based on the statistical report, the support team and volunteers will provide the survivors with the necessary food, drink, and medicine, as well as suitable places for living.
3. Construction workers as a support team with the help of volunteers will remove the debris caused by the disaster.
4. As a support team, construction workers will rehabilitate infrastructure and housing in the disaster-affected area.
5. Technicians as a support team will rehabilitate the SDMS and its associated equipment with a thorough inspection of all parts of the system to make sure they are working properly.
6. After the completion of the rehabilitation process, the team leader assesses the performance of the risk management team, supporters, and volunteers. He will analyze the speed of response and the way to better deal with the disaster. A copy of this report will be sent to the database to be saved as historical data training for the future.
7. The team leader announces the end of the disaster and orders the team to return to standby mode.

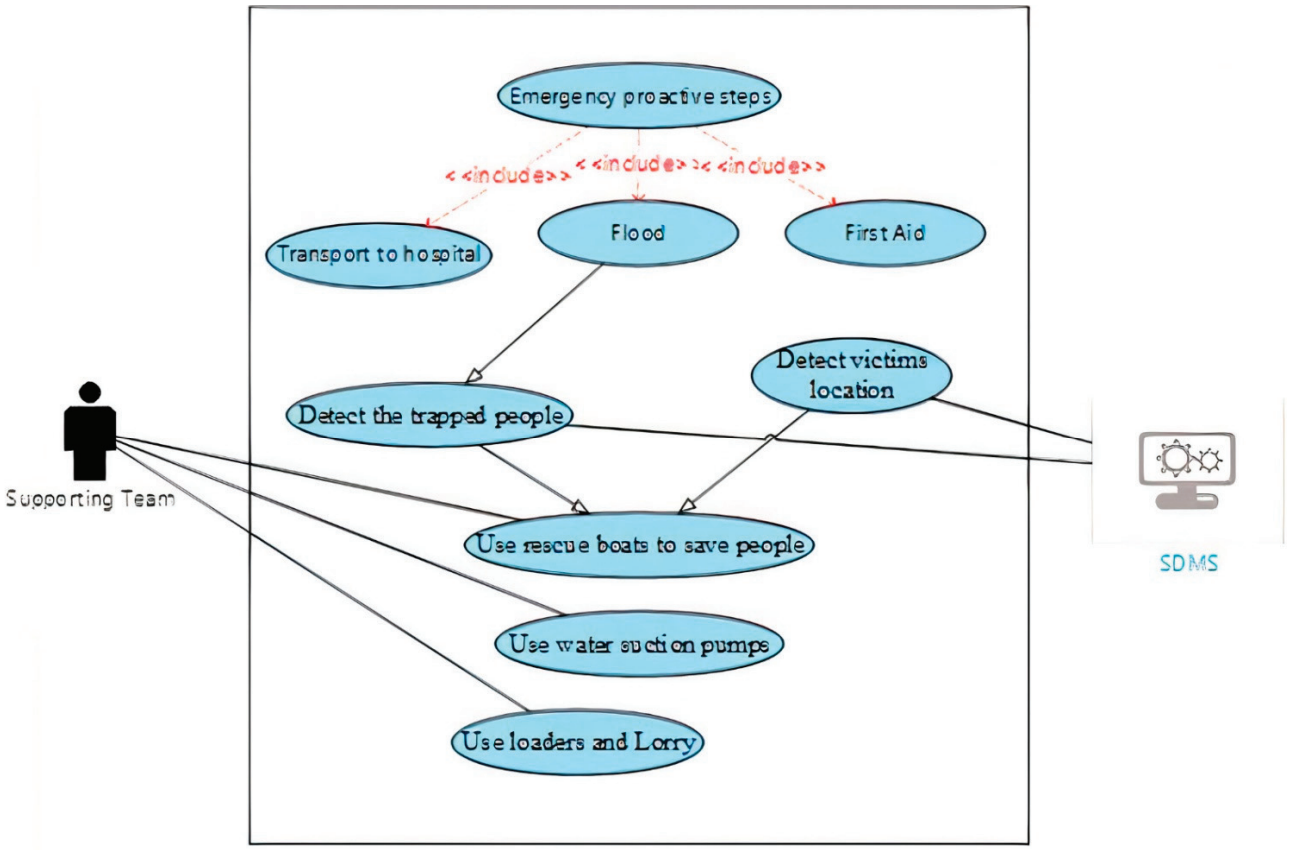

Figure 4. Use case diagram of during flood disaster stage [39].

Figure 5 below shows the activities and the responsibilities of the disaster team in the after flood disaster stage, represented in a Use case diagram. This figure also shows the important role of the SDMS and the DB in this stage.

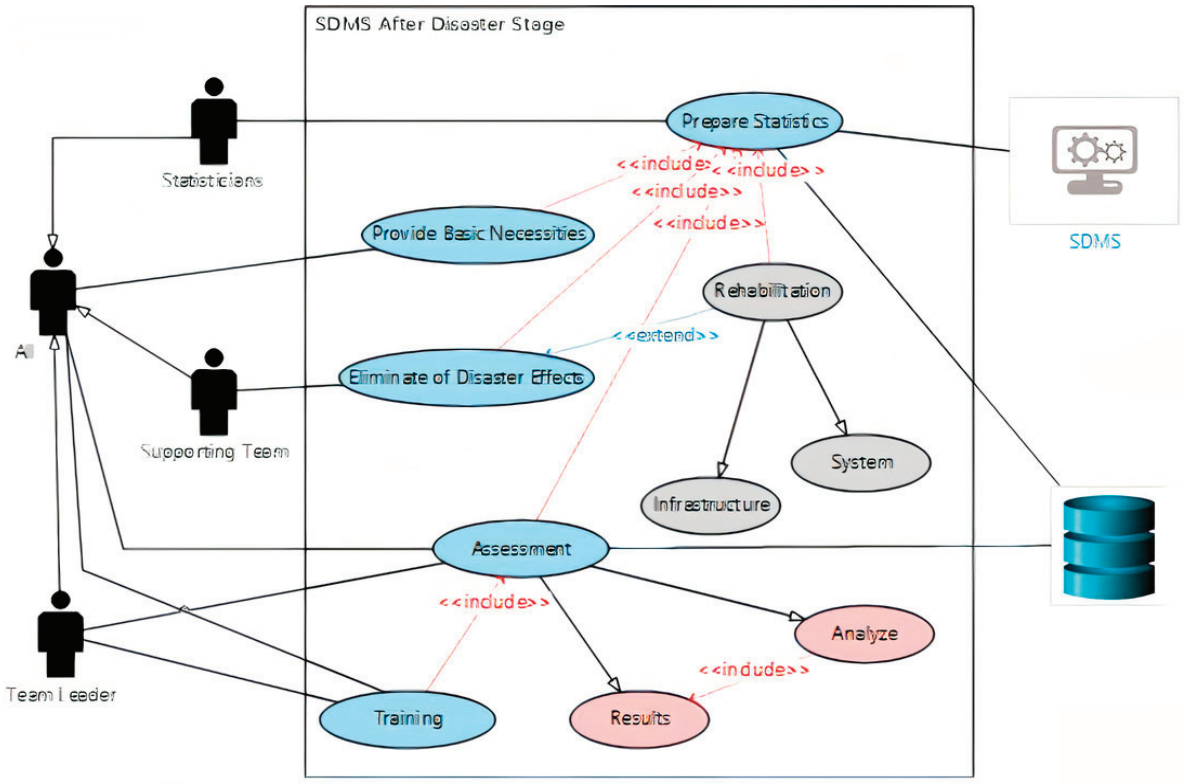

Figure 5. Use case diagram of after flood disaster stage [39].

5. Discussion

Natural disasters lead to geographic changes in the lives of people [41]. The goal of a DMS is to minimize the impact of a disaster [42]. In a similar manner, the United Nations Office for Disaster Risk Reduction (UNDDR) has defined disaster risk management (DRM) as "the process of using directives, organizations, and capacities to implement strategies policies, and improve capacities in order to decrease the impact of disasters" [43]. This system contains four facets: mitigation, preparedness, response, and recovery. All these facets are wholly dependent on IT [44]. The weakness of the existing DMSs is related to technical along with administrative vulnerabilities. This issue was argued by Nowell et al. [45], wherein they stressed that the success of the DMS relies on a change in the administrative structure of this system, making all units of the system linked to one administration and receiving orders from only one leader, in addition to linking all units of the system with each other by ICT.

Increasing the readiness of citizens towards disasters as well as increasing their ICT knowledge will contribute in reducing the effect of these disasters. The researcher agrees with this reflection, and it will be approved after the implementation of the SDMS. One of the most prominent challenges facing the implementation of the DMS is the high cost of the components of this system; therefore, most researchers in this field rely on conceptual design when trying to apply new ideas to this system [46]. For all the previous reasons, a conceptual design for an enhanced DMS called SDMS was proposed. Unified modelling language (UML) is used to describe the system structure and behavior. The interaction between different actors in the system is specified with use cases as part of UML diagram [47]. Interlinking every department through IoT allows to reduce the damages of disaster. Sensor networks, IoT, and embedded system structures can be used for the smart networks for emergency control management [33]. A metamodel-based knowledge sharing system for disaster management based on UML was proposed by Othman, and Beydoun [48]. They deploy the transformations specified in the meta-modelling framework of MOF, a standard for software metamodeling offered by OMG [49]. MOF defines a

common way for capturing the diversity of modelling standards and interchange constructs that are used in model-driven software engineering. Othman and Beydoun [48] further argued that it provides a framework for defining modelling languages or information models for metadata. It uses an object-modelling framework that is essentially a subset of the UML core [50]. The application of ICT and IoT supports E-government services to facilitate in predicting and altering the consumers in order to reduce the damage caused by natural disasters and pollution [51]. Goniewicz and Burkle [52] developed an IT system for Poland's Protection Against Extreme Hazards (ISOK); this system works to reduce the damages of physical and moral disasters to citizens by developing a crisis and risk management mechanism. In a similar way, another important system was implemented in Poland called the Sat4Envi project; this system works to gather, share, and promote for the environment by analyzing satellite images and obtain data related to disasters in order to forecast disasters in study by Goniewicz et al. [53].

In this research, a framework for enhancing the current DMS called SDMS is proposed. Here, the smart aspect of this system is due to the application of the principles of ICT, IoT technologies, and UML applications. This effort was made as part of doctoral study to overcome the lack of citizens' readiness towards the application of ICT as well as an increase in their readiness towards handling such disasters.

6. Conclusions

The globe is exposed to various types of disasters; some of these disasters are natural and some are man-made. These disasters result in a substantial loss of life and property. Over the years, researchers have tried to control these disasters and reduce their losses. This research discussed the possibility of using (ICT), especially E-government applications, and the IoT in disaster management. The success of flood disaster management depends mainly on how well flood-related data can be collected, managed, and utilized. Due to this account, the application of IoT to facilitate flood data management is seen as a step in the right direction.

The concluding part of this research is proposing an enhanced DMS called SDMS in order to increase the readiness of citizens by applying recent ICT technologies such as IOT and AI to handle disasters. Where a conceptual design for the SDMS is prepared, this conceptual design contains a scenario for each stage of the disaster management system's stages (before disaster, during disaster, and after disaster). UML diagrams are prepared for each stage to illustrate the participants, activities, and position of each person within the system. This will help in developing a conceptual design that can facilitate in the development of a smart management system for flooding disaster. This will also assist in the design process of the IoT systems in this regard.

In this conceptual design, the researchers tried to provide a general vision for the system developers, programmers, software engineers, and designers to work on system details, each according to their specific requirements (context) in order to stimulate their creativity. Therefore, this study did not address the implementation of such systems, for instance: specific type of devices, operating systems, databases, etc.; this may represent a kind of limitation for this research study. As future research directions, an integrated information system approach to the early warning of floods based on a geographical information system (GIS) and remote sensing could be designed and developed. Additionally, the implementation issue of such systems could be conducted as a case study with support from government agencies and related organizations.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author Contributions: Conceptualization, T.I. and A.M.; methodology, T.I.; software, T.I.; validation, T.I. and A.M.; formal analysis, T.I.; investigation, T.I. and A.M.; resources, A.M.; data curation, T.I.; writing—original draft preparation, T.I. and A.M.; writing—review and editing, T.I. and A.M.; visualization, T.I.; supervision, A.M.; funding acquisition, A.M. All authors have read and agreed to the published version of the manuscript.

Funding: The APC is funded by Molde University College-Specialized University in Logistics, Norway.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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International Journal of
Environmental Research and Public Health

MDPI

Article

The Feasibility of Implementing the Flexible Surge Capacity Concept in Bangkok: Willing Participants and Educational Gaps

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Citation: Phattharapornjaroen, P.; Glantz, V.; Carlström, E.; Dahlén Holmqvist, L.; Sittichanbuncha, Y.; Khorram-Manesh, A. The Feasibility of Implementing the Flexible Surge Capacity Concept in Bangkok: Willing Participants and Educational Gaps. *Int. J. Environ. Res. Public Health* **2021**, *18*, 7793. https://doi.org/10.3390/ijerph18157793

Academic Editor: Paul B. Tchounwou

Received: 12 April 2021
Accepted: 20 July 2021
Published: 22 July 2021

Abstract: The management of emergencies consists of a chain of actions with the support of staff, stuff, structure, and system, i.e., surge capacity. However, whenever the needs exceed the present resources, there should be flexibility in the system to employ other resources within communities, i.e., flexible surge capacity (FSC). This study aimed to investigate the possibility of creating alternative care facilities (ACFs) to relieve hospitals in Bangkok, Thailand. Using a Swedish questionnaire, quantitative data were compiled from facilities of interest and were completed with qualitative data obtained from interviews with key informants. Increasing interest to take part in a FSC system was identified among those interviewed. All medical facilities indicated an interest in offering minor treatments, while a select few expressed interest in offering psychosocial support or patient stabilization before transport to major hospitals and minor operations. The non-medical facilities interviewed proposed to serve food and provide spaces for the housing of victims. The lack of knowledge and scarcity of medical instruments and materials were some of the barriers to implementing the FSC response system. Despite some shortcomings, FSC seems to be applicable in Thailand. There is a need for educational initiatives, as well as a financial contingency to grant the sustainability of FSC.

Keywords: alternative care facilities; disasters; flexible surge capacity; major incidents and disasters; surge capacity

1. Introduction

The rate of major incidents and disasters (MIDs), irrespective of the causes, has gradually risen over the past two decades. A major proportion of these incidents are triggered by natural hazards as a result of climate changes and can result in potentially deadly consequences [1]. MIDs can result in overwhelming numbers of physical and mental injuries, and lead to socioeconomic challenges, which can surpass healthcare response capability and capacity [2–5]. The most significant goal of the healthcare system during a MID is to provide care to victims and minimize their suffering by using available resources. The emergency management organization has to facilitate preparedness and relief measures

to create a well-organized contingency plan. However, the ability to manage surge capacity is central to consolidate and optimize the system.

Surge capacity consists of four essential elements: staff, stuff (devices), structure (spaces), and system. All elements focus on three levels of healthcare operation; public-based, hospital-based, and community-based [6–8]. Each level has its capabilities and limitations regarding surge capacity in all phases of an emergency. In a critical situation, hospitals will try reallocating patients or medical equipment (like ventilators), conducting primary and secondary surge capacity, but the overflow of patients might still outstrip their ability and result in unpredictable consequences, as illustrated in northern Italy during the COVID-19 pandemic in 2020 [9]. Therefore, the amplification of MID consequences requires another effort of surge capacity, i.e., "flexible surge capacity" (FSC). FSC aims at scaling up and down all viable resources in the community in terms of all four elements of surge capacity mentioned above [10–12]. As an example, in a previous study, using emergency physicians as alternative leadership in the management of MIDs was discussed within the concept of FSC [10,13]. Other reports have also pointed out the importance of systems and rules in MID management [14]. However, there are limited studies investigating the use of Alternative Care Facilities (ACFs), which are places that can potentially be modified into treatment stations for disaster-related patients or non-disaster patients, to incorporate the structural needs during MIDs as the FSC [15,16]. The concept of FSC and the use of ACFs were found to be feasible in Sweden, but it may be unfeasible in other countries with varied structures and cultures [10,11]. Nevertheless, the current COVID-19 pandemic demonstrates a global concern about ACFs and forced many healthcare organizations to adapt schools and private clinics into isolation or vaccination areas, while others either rapidly modified some parts of the hospitals or one small hospital for critical and pandemic care [15–17].

Thailand has experienced several MIDs (e.g., tsunamis and terrorism) [2], and difficulties regarding structure and system elements of surge capacity during crises. There have been efforts to enhance multi-agency partnerships like civil and military collaborations to strengthen the MID management system. However, there is no consensus regarding organized collaboration routines and procedures. The accomplishment of FSC may provide an opportunity to utilize institutional, governmental, and private actors' resources to achieve routines and consensus about the multi-agency management of emergencies. Such an achievement may provide a model for low and middle-income countries, especially in Asia. This study aimed to investigate the feasibility of implementing FSC response systems by examining the needs for, and the possibility of using ACFs, as well as examining any potential barriers to them.

2. Materials and Methods

Venue: For this study, ACFs in Bangkok, Thailand, including public primary healthcare, private, dental, and veterinary clinics, schools, sports arenas, and hotels, were investigated. The reason for choosing Bangkok was the existing variability and the substantial number of potential facilities in the city.

Sample: The names and locations of public primary healthcare centers, private clinics, and dental clinics were obtained from the Ministry of Health in Bangkok. The names of schools were obtained from the Department of Education. Veterinary clinics, hotels, and sports arenas were searched for online through available websites. The sampling for government-related institutions was conducted by the Ministry of Health and Department of Education officials, and the authors had no influence on the selection. For other facilities, all available facilities were contacted and received the questionnaire. However, the authors had no influence on the response from these facilities, and despite multiple contacts, only those with complete responses were included.

All aforementioned facilities received the questionnaire. The ministries, department, and responsible persons in each facility were contacted by the main author to decide

whether the questionnaire should be distributed centrally or by sending to each individual entity.

The Questionnaire (Supplementary A): An already published and validated questionnaire (Cronbach's alpha with an internal consistency of 0.739 [18]) was utilized [11]. It was translated into Thai and then back into English to assure the accuracy of the questions. The face validation of the original questionnaire was based on logic, relevance, comprehension, legibility, clarity, usability, and consensus. The questionnaires referred to a situation that the facilities of interest faced, a fictitious scenario of a mass casualty incident. ACFs were asked about the care they could provide to the healthcare actors in the area.

There were both open-ended and close-ended questions to capture and generate relevant data, and the answers were quantitatively collected [19,20]. The quantitative data dealt with the number of participants, who received the questionnaire and the number of those responding, and, thus, the rate of participation. No other quantitative data were presented.

The qualitative data were collected by semi-constructive interviews, which in contrast to a structured interview technique, allows the participant to divert and suggest new ideas during the interview based on responses. The interviewer in a semi-structured interview generally has a framework of themes to be explored [21]. All data were recorded and analyzed by the first investigator.

The theme applied to the interview was the one used in Glantz's study (2020) [11], which used the same questionnaire and interview questions. For analyzing, we deductively used the distribution of the concepts of surge capacity, which allows for examining communication by using text directly. This method allows for both qualitative and quantitative analysis if needed. It is also considered a relatively exact research method if it is done correctly (limitation). It is an inexpensive research method and considered a more powerful tool when combined with other research methods such as interviews. However, it also has its limitations (see limitation). Thematic content-coding was performed to identify competencies, challenges, and interest to take part in the FSC response system. No more interviews were held after reaching the point of data saturation [20].

3. Results

From the sample of 967 names and addresses of the facilities, 228 responses (23.6%), were collected through Google forms. Participants who replied to the questionnaire answered all of the questions. However, the response rate varied in the different groups (Supplementary B).

The highest response rate was the public primary healthcare centers (PHCC) at 50.7%. Only 13 out of 185 private clinics responded (7%) (Table 1). Additionally, municipal schools with less than 500 students were excluded since they were considered to be too small to provide help in the FSC response system. The absolute number of facilities and respondents after exclusion was 739 and 162 (21.9%), respectively.

Table 1. The response rate of all ACFs in Bangkok.

Alternative Care Facilities	Number of Facilities	Number of Response (%)
Total	967	228 (23.6)
Public primary health care centers	69	35 (50.7)
Private clinics	185	13 (7)
Dental clinics	116	17 (14.6)
Veterinary clinics	90	14 (15.6)
Schools	437	136 (31.1)
Sport facilities	12	5 (41.7)
Hotels	58	8 (13.8)

After responses were returned from potential ACFs, the phone interviews were conducted with directors, owners, and administrators of the facilities. Face-to-face interviews were not attainable due to the social distancing policies and the shutdown of public services to mitigate the COVID-19 pandemic. The questions were discussed in-depth during 15–30 min interviews with directors from ten primary health care centers, six private clinics, two dental clinics, two veterinary clinics, one school director, one sports facility administrator, and one hotel owner.

3.1. General Results

The majority of alternative care services voluntarily offered their facilities in the event of a MID. A considerable number of both public primary healthcare and dental clinics proposed to manage patients with minor injuries, manage mild medical conditions, provide psychosocial support, communicate to emergency medical services, and transport severely injured patients to hospitals. Interviewees from these facilities raised concerns over unproportioned staff supply, physical space, medical equipment, and material resources. Veterinary clinics, schools, and sports halls were interested in providing their particular facility to house an ACF. All facilities showed an interest in taking part in educational initiatives such as training in first aid, cardiopulmonary resuscitation (CPR), major trauma care, and the transportation of victims. Some facilities reported the benefits to specifically enhance their performance in MID management. Nevertheless, the shortage of medical supplies was one of the apprehensive barriers of non-healthcare facilities' administrators.

3.2. ACF Specific Results

3.2.1. Health Care Clinic

Health care clinics in Thailand exist within two particular systems. Firstly, the public primary healthcare centers (PHCC), governed by the Ministry of Health, have doctors, nurses, and pharmacists. The PHCCs provide routine treatments for patients with chronic diseases and minorly acute illnesses. Private clinics, which operate independently, yet require a license from the Ministry of Health, have a doctor, and either a nurse or assistant nurse. Most private clinics are specialty clinics providing care for specific niches like pediatrics allergies or dermatologic issues. Thirty-five out of sixty-nine public primary healthcare centers and thirteen out of one-hundred-and-eighty-five private clinics responded to the questionnaire. A substantial number of respondents possessed the capability to serve in the FSC response system by treating fewer injured people and providing psychosocial support to patients and staff. The public centers would prefer to stabilize patients physiologically before transport to a major hospital. Furthermore, a limited number of private clinics offered their staff and stuff to either treat at their clinics or move their personnel to affected facilities. Two of them offered no potential to be included in an FSC response system (Table 2).

In addition, more than half of the respondents (twenty-one public centers and ten private clinics) commented that they lacked essential medical equipment including advanced defibrillators, intubation equipment, and resuscitation medications. Moreover, increased space, extra ambulance vehicles, and more emergency kits would ease and encourage their contribution. The in-depth interviews highlighted this insufficiency in both public and private healthcare facilities. Although all public facilities had doctors and nurses, and some centers had pharmacists to include in a potential FSC, the qualitative data collection revealed barriers in private clinics' willingness to contribute doctors or nursing assistants. Furthermore, many respondents requested training in advanced life support, emergency and trauma case management, disaster management, and prehospital transportation in their interviews. Though most respondents offered constructive criticism, a limited number of answers (three public clinics and five private clinics) responded negatively toward any kind of involvement.

Table 2. Questionnaire data of potential support that clinics could provide.

Choices of Provided Facilities	PHCC (35)	Private Clinic (13)	Dental Clinics (17)	Veterinary Clinics (14)
Fewer injured patients from the incident	30	10	16	14
Stabilization of seriously injured patient before transfer to major hospital	12	1	1	1
Other hospital emergencies	6	1	2	0
Assisting the hospital	6	1	3	0
Resources; space, instruments, materials	6	1	1	2
Minor procedures	5	0	2	1
Medical patients	10	0	1	0
Psychosocial support to patients and staff	21	3	5	1
Coordination of home transportation	10	3	3	0
Cannot help	1	2	0	0

3.2.2. Dental Clinics

All dental clinics in Bangkok represented private practices and provided a wide range of dental procedures. From the one-hundred-and-sixteen clinics contacted, seventeen responses were received. Sixteen out of seventeen clinics responded they could provide care to patients with minor injuries in the event of a MID. Approximately one-third of clinics were willing to offer psychosocial support to patients and staff. Several expressed a willingness to perform minor surgical procedures and treat other acute cases to relieve the hospital emergency department. Additionally, one dental clinic offered space, instruments, and materials, and another expressed the potential to stabilize a patient before transfer to a major hospital. Ten clinics lacked equipment and devices, such as automated external defibrillators (AEDs), monitor sets, medical oxygen tanks, and splinting material. Additionally, all clinics commented they would voluntarily support FSCs if they received more education in emergency care. Two clinic owners interviewed expressed confidence in managing all dental injuries and minor wound care, but not overall MID management (Table 2).

3.2.3. Veterinary Clinics

All veterinary clinics were private actors. We received fourteen responses from the ninety contacted facilities, and all respondents reported an ability to participate in FSC. All of them indicated that they would be able to offer treatment for minor injuries from the incident. One clinic expressed the ability to perform minor surgery and provide wound treatment. Another clinic indicated that it could offer support for psychosocial issues as part of an FSC system. Two of them had physical space which could be utilized to provide any kind of care in MIDs. Most of the clinics were concerned about their jurisdiction in human injury management (Table 2). It was perceived from the forms and interviews that veterinarians thought they were obligated and permitted to handle only animals. Nonetheless, three out of fourteen clinics were interested in improving their knowledge of human life-saving procedures.

3.2.4. Schools

Only municipal schools from the Ministry of Education were contacted in this study. A sum of 136 out of 437 replied from schools with a student population ranging from 100 to more than 2000. Because of the requirements for FSC, only institutions with significant staff, space larger than 3000 square meters, and with more than 60 employees were included from the entire set of respondents (n = 70). Absolute numbers of respondents comprised 70 schools, of which 23 reported their abilities to stop bleeding, repair wounds, administer CPR, and perform emergency procedures. Half of the participants expressed a willingness to manage minor injuries and offered care for children. All institutions had a small treatment room to look after sick or injured staff as well as students. The room

displayed medical equipment such as first aid kits, blood pressure cuffs, and thermometers. A few schools identified it as a relevant resource to the collaboration with nearby primary care centers and hospitals in case of emergencies. Almost all respondents voiced that they demonstrated no readiness to manage the situation because of their shortage in manpower and skills. However, 23 of the respondents communicated their enthusiasm for participating in training drills in resuscitation and emergency care to be prepared for daily student injuries and incidents. Additionally, one of the institutions proposed a segment for medical treatment to be included in their academic curriculum, while another preferred to generate their own MID management plan (Table 3).

Table 3. Questionnaire data of potential support those facilities could provide.

Choices of Provided Facilities	School (70)	Sport Facilities (5)	Hotel (8)
Stop bleeding, wound management, or emergency procedures	23	2	1
Minor injury	35	5	3
Psychosocial support to patients and staff	25	1	2
Shelter for homeless or injured people	8	1	8
Food and water	30	0	8
Childcare for health care staff	35	1	4
Share own staff with other organization	10	0	0
Cannot help	0	0	0

3.2.5. Sports Facilities

All sports centers were municipally operated and had a small medical clinic with either nurses or assistant nurses who were trained in first aid and wound care. Five out of twelve sports centers returned questionnaires, and the forms were sufficiently answered by the directors of the facilities. All respondents were interested in the FSC response system and reported to be capable of managing minor injuries. Two of them could stop major hemorrhages and repair wounds, and one of them could offer homeless or affected people accommodation as well as psychosocial support. Three out of five sports centers reported being uncomfortable when confronted by MIDs due to a lack of manpower and material (Table 3).

3.2.6. Hotels

Eight out of fifty-eight questionnaires were returned. All of them showed an interest in participating in the FSC response system as temporary housing facilities and sources of water and food for people concerned. Three hotels reported their potential to manage minor injuries. Four hotels offered childcare assistance to parents that might be needed during the activation of an FSC system. One of the hotels reported that staff were educated with annual first aid courses. Nevertheless, all hotels expressed shortcomings in educational initiatives and medical supplies (Table 3).

4. Discussion

The most interesting outcome of this study was the increased awareness of participants and authorities involved in the need for a FSC system. The involvement of authorities allowed for the conduction of the study in both disseminating the questionnaire and returning respondents' comments. Results also demonstrate the willingness of carrying out FSC in Bangkok among participants. MID management demands a multi-agency approach. From this perspective, this study also indicates different organizations may be able to collaborate to achieve the concept of FSC. However, there are some requirements that should be fulfilled to achieve a successful FSC [10,11,22–24]. Staff, stuff, structure, and system (4S) remain the significant elements of the FSC response system. Previous researchers have identified the necessity of surging capacity during MIDs [6,25,26]. FSC aims to activate

other resources that are not usually considered in contingency plans. These resources can be generated, as shown in this study, within a community by using its own pool of resources. As noted by the World Health Organization (WHO), this process is part of striving to reach the Sustainable Development Goal 11 of developing community resilience [27]. The provision of alternative central or local leadership by offering command and control to the public health agency and emergency physicians, respectively, has already been introduced [10,13]. There has been a discussion in the literature regarding ACFs and their importance [15,16]. This paper aimed to highlight the possibilities for ACFs in the metropolitan area in an emergency-prone country [28]. The knowledge of staff, stuff, and structure enables the development of necessary rules, regulations, and systems.

The maximization of the potential ACFs, together with a well-organized system, can significantly improve the survival of victims. In addition, the key to initiate change and advance the system forward is not only the availability of resources but also the willingness of organizations to collaborate. The results of this study positively display the willingness of facilities to alleviate hospitals and partake in a response to a MID. Although the number of responses was limited, the study showed that the majority of participants were willing to alleviate the burdens of MIDs. These participants represent the facilities' leadership. The choice of respondents is based on the assumption that the leadership has an overview of the organizational capacities and the ability to act as the voice of the staff [29]. The four components of surge capacity will be discussed below.

4.1. Staff

Not only the quantity of personnel but also the quality of manpower is one of the essential elements in the FSC response system. Competent workforces influence disaster management and reflect a well-structured incident command system. Staff should possess appropriate credentials and recognize their roles and their facility's disaster response plan. Furthermore, proficient leadership is critical to promote a more superior command and control of the staff and result in efficient MID response [13]. This study showed a significant number of staff in the investigated facilities of interest were willing to partake in the response system. Nevertheless, they raised concerns regarding knowledge, confidence, and discomfort in procedural techniques. The results of several studies are congruent with the one in this study. Both healthcare and non-healthcare personnel volunteered as emergency responders in case they received proper training [10,24,30,31]. This result differs from a Swedish study in which non-healthcare staff were unwilling to partake in MID management due to a lack of competency [11]. To resolve the problem with the lack of competency among staff, short-term recommendations are to establish a dynamic personnel base and staff pooling across facilities, or recruit solicited employees like retirees, as well as unsolicited employees [6,7]. In a long-term development, the establishment of first aid, emergency procedures, patient transfer, and psychosocial support courses with annual re-certification would represent a suitable strategy to empower staff to participate in the FSC response system [11,30,32].

4.2. Stuff (Health Care Equipment and Materials)

The scarcity of medical equipment and materials during MIDs in the past had a global impact [8,11,24,26,33]. The facilities of interest investigated in this study are proportionally unequipped to serve victims with severe injuries, which in turn means that their stockpiles and their capacities to replenish them are limited. The investigated facilities were unprepared for mass casualty events, although they showed a willingness, capacity, and capability of doing so [11]. Many also expressed a need for qualified resources in order to be able to partake in a FSC response. Moreover, financial stability and contingency funding, along with a rapid acquisition and distribution system of medical instruments and materials, should be discussed beforehand to prevent any depletion of resources [8,25,26]. The reallocation of medical instruments and devices to both public and private actors is

one of the crucial steps in MID management that also need collaboration and coordination among facilities [25].

4.3. Structure

Most of the investigated facilities had their own treatment areas, including sports centers and schools, however, the sectors were initially designed to fit a compact group of people at any one time. A rearrangement of instruments, devices, and materials is needed to increase utilizable spaces like patient bed areas, treatment areas, counselling areas, and operation areas. Primary healthcare, dental, and veterinary clinics occupied more suitable spaces, as some of them already utilized a sterile area for minor operations, and their whole floor was often structured for the provision of medical care. Therefore, they demanded only minimal retrofitting and they would be more equipped to handle the situation than non-healthcare facilities such as sports centers, schools, and hotels [11]. Despite the limited treatment area in sports facilities and schools, they possess enormous vacant fields that can act as an area to construct novel nursing zones for victims. In addition, a civil and military collaboration could organize and manage a field hospital and military transportation which could be another one of the options to utilize schools and sports arenas [24]. Moreover, one example of a recent MID was the first wave of COVID-19 pandemic in 2019 that triggered the surge capacity of the structures needed in many countries to alleviate the burden of the major hospitals [24,33]. The event justifies the concept of a FSC response system, however, the efforts need to be drilled, trained, and practiced [10,11,34].

4.4. System

In Thailand, there was an outstanding difference between public and private organizations. While more than 30% of governmental institutions declared their intention to assist, only 11% of the private actors answered the forms, which indicated a lack of interest in the issues, and they have an unclear line of command because they are independently governed, and the Ministry of Health has no power over them. One possible reason for the lack of interest from private actors can be the differences in financing. While public organizations are financed by taxes, private actors have no government funding for disaster preparedness and humanitarian work. Consequently, regulations are needed to secure participation from all types of actors. Nevertheless, when a MID occurs, the need for involvement by all relevant actors is unavoidable. Therefore, the private sector should establish a command system that corresponds with the national system. The collaboration between the private and public sectors would advance with the urge of the Ministry of Health to exhibit the corresponding guidelines and protocols [35–37]. Although the Swedish results for differences between public and private actors were inconclusive, the governing system in Sweden offers municipal and community independence, which means that government can only recommend necessary measures [11].

To create a robust MID management system, multi-agency collaboration regarding surge capacity and the systematic organization of resources is recommended. Inter-agency partnership cannot be a spontaneous action or initiative, as it is a challenge to perform smooth communication and co-operation during MIDs. Therefore, exercises, training, and practice guidelines may empower both public and private organizations to learn how to work together in emergencies like hospital evacuations [2,13,14,34,38,39].

5. Limitation

The results of this study are from one urban Asian society. A similar study in a non-urban society could lead to a different outcome. Despite several efforts, the response rate in this study was low. One reason for the low participation rate might be the perception of disasters as being rare events, as the awareness of MIDs is low among the Thai population, government officials, and business stakeholders. Another reason for low participation might be the fact that disaster management is based on both medical and non-medical measures. There might be a limitation in understanding between organizations involved,

i.e., non-medical institutions having limited knowledge about the limitations and possibilities of medical institutions and vice versa [24]. In this study, top authorities were contacted to improve the response rate with low success. However, the response rate is concordant with previous non-pandemic studies. In future studies, electronic repeated reminders might improve response rates [40–42].

Finally, the content analysis is subject to error, particularly when a relational analysis is used to attain a higher level of interpretation. Nevertheless, the main investigator was part of a similar study published in 2020 and therefore had prior experience with the analytical method.

6. Conclusions

The concept of a FSC response system is applicable to the metropolitan area of this study where several clinics, schools, and hotels exist. New studies will reveal if the apprehensive points could be generalized to other countries with the same context. However, the development and implementation of educational initiatives including exercises, drills, maintenance courses, and financial contingency were recognized to be barriers necessary to overcome in the implementation of the FSC concept. The success of overcoming these barriers would enable sustainable FSC systems to be developed within the MID response system.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/ijerph18157793/s1, A: Information Sheet, Questionnaire and interview guide, B: Research data.

Author Contributions: Conceptualization, P.P. and A.K.-M.; Data curation, P.P.; Formal analysis, P.P. and A.K.-M.; Investigation, P.P.; Methodology, P.P., E.C. and A.K.-M.; Resources, P.P.; Supervision, A.K.-M.; Validation, P.P., V.G., E.C., L.D.H., Y.S. and A.K.-M.; Visualization, P.P. and A.K.-M.; Writing—original draft, P.P.; Writing—review & editing, P.P., V.G., E.C., L.D.H., Y.S. and A.K.-M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Human Research Ethics Committee, Faculty of Medicine Ramathibodi Hospital, Mahidol University (protocol code MURA2020/1621 and date of approval was 5 October 2020).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

Acknowledgments: The authors would like to acknowledge Emily Jeanne Glantz for academy English revision.

Conflicts of Interest: The authors declare no conflict of interest.

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International Journal of
Environmental Research and Public Health

MDPI

Article

Implementing Public Health Strategies—The Need for Educational Initiatives: A Systematic Review

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Abstract: In the absence of a specific treatment or vaccines, public health strategies are the main measures to use in the initial stages of a pandemic to allow surveillance of infectious diseases. During the ongoing global pandemic of coronavirus disease 2019 (COVID-19), several countries initiated various public health strategies, such as contact tracing and quarantine. The present study aims to conduct a systematic literature review to identify the presence of educational initiatives that promote the implementation of public health strategies before public health emergencies, with a special focus on contact tracing applications. Using Science Direct, PubMed, Scopus, and Gothenburg University search engines, all published scientific articles were included, while conference, reports, and non-scientific papers were excluded. The outcomes of the reviewed studies indicate that the effective implementation of public health strategies depends on the peoples' willingness to participate and collaborate with local authorities. Several factors may influence such willingness, of which ethical, psychological, and practical factors seem to be the most important and frequently discussed. Moreover, individual willingness and readiness of a community may also vary based on the acquired level of knowledge about the incident and its cause and available management options. Educational initiatives, proper communication, and timely information at the community level were found to be the necessary steps to counteract misinformation and to promote a successful implementation of public health strategies and attenuate the effects of a pandemic. The systematic review conducted as a part of this study would benefit the relevant stakeholders and policy makers and assist with effective designing and implementation.

Keywords: contact tracing; ethics; pandemic; psychology; public education; public health

Citation: Khorram-Manesh, A.; Dulebenets, M.A.; Goniewicz, K. Implementing Public Health Strategies—The Need for Educational Initiatives: A Systematic Review. *Int. J. Environ. Res. Public Health* **2021**, *18*, 5888. https://doi.org/10.3390/ijerph18115888

Academic Editors: Peng Bi and Paul B. Tchounwou

Received: 26 April 2021
Accepted: 28 May 2021
Published: 30 May 2021

1. Introduction

The unpredictable development of the coronavirus disease 2019 (COVID-19) resulted in a global pandemic beginning in 2020, spreading from one region to another [1]. Consequently, countries had to rely on traditional public health measures such as isolation, containment, quarantine, and contact tracing strategies [2–6]. However, these urgently implemented measures had varying success in halting the spread of the disease globally, either due to shortcomings in countries' infrastructure or their financial capabilities. New waves of viral infection started spreading again as soon as society opened up [3,6].

In response to the worsening situation, several countries started various means of contact tracing and isolation of their citizens [7–12]. Contact tracing represents one strategy, which slows down the spread of the viral infection and enables the identification of infected

cases or those at risk, either by listing all people with whom an infected person has recently been in contact, or by using location-tracking mobile applications (apps) [7–11,13–16]. There has been an intensive development of contact tracing applications (CTA), using various means of technology, including QR (Quick Response) codes; GPS (Global Positioning System); credit card transmission log; CCTV (Closed Circuit Television); different COVID alert apps; and Bluetooth [1,10–20]. However, the inadequate level of public compliance with these public health strategies has resulted in mandatory contact tracing strategies as part of a government strategy in some countries [8,17,21]. Within the European Union (EU), in some nations, authorities together with telecommunications providers started sharing people's anonymous location data on map concentrations, respecting the Europe's privacy laws and individuals' rights to privacy [8,9,21–27].

Although the use of these apps seems necessary and beneficial, they seem to create several challenges, such as ethical, psychological, and practical, that may influence the willingness of individuals and a community to implement these measures actively [22,23,25]. The willingness itself is proven to be dependent on the level of information and knowledge, especially when dealing with unknown threats [28]. Adequate knowledge about incidents, their etiology, and the available management options enables recognition of the threats and acceptance of necessary strategies during public health emergencies. Consequently, community preparedness and mental readiness seem to be some of the most important elements in successful policy implementation [20,29–44]. It is therefore evident that investing in local empowerment by establishing educational initiatives, proper communication, and timely information are all necessary steps to counteract misinformation and to promote successful implementation of public health strategies, which will further attenuate the pandemic.

The present study aims to conduct a systematic literature review to identify the presence of educational initiatives that promote the implementation of public health strategies before public health emergencies, with a special focus on contact tracing applications. It also aims at opening discussions and creating a basis for the exchange of information from the countries implementing similar solutions, especially European countries, with which joint actions could be undertaken.

2. Materials and Methods

This review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and its flow diagram [45]. The searching process included articles and the PRISMA checklist for each considered study and abstract were completed and attached to this manuscript (Appendices A–C). The scientific evidence of each selected article was assessed, by using the Health Evidence Quality Assessment Tool (Appendix D), as Strong, Medium, and Weak [46]. Initially, Google Scholar was used as the testbed to estimate the number of hits and adjust the searching keywords accordingly. In the next step, Science Direct, Scopus, PubMed, and Gothenburg University's Super search engines were used for a systematic search. The inclusions criteria were original research studies published in English. The exclusion criteria were conference papers, abstracts, reports, and non-scientific publications.

The research group performed the initial screening of all abstracts and titles independently to determine whether to include or exclude an article based on pre-defined selection criteria. The content analysis method was used to assess the eligibility of included papers, focusing on similarities and differences in the findings to present the tentative results [47]. During the abstract and title screening phase, a level of agreement on inclusion and exclusion was achieved among the authors. The third author reconciled disagreements (if any) between the first two authors to achieve a mutual consensus before moving to the full-text review. The full-text articles were assessed for inclusion, and the reasons were documented for all the excluded papers. The outcome was grouped based on the content analysis into four topics: practical, ethical, psychological, and educational aspects of public

health emergency measures. Appendix A shows the combination of used search keywords and Table 1 illustrates the information about included studies. The key terms are as follows:

- Public Health Strategies
- Public Health Emergency
- Contact Tracing
- Isolation
- Quarantine
- Public Education

A standard data extraction form was used to collect the authors, article title, year published, journal title, study design, brief description of methods, primary outcome measures, and conclusions by all the authors for the articles included for full-text inclusions in the last step. References of the papers initially found were not included for evaluation. The search results from each database were exported to Microsoft Excel, merged, and sorted for removal of duplicate citations. Each article's reference list was checked to identify reliable and relevant articles for inclusion into the final review list.

Table 1. Shows the included studies, health evidence, information about authors and their affiliation, year of publication and the main topic of discussion, journal, and subject description. Topics are shown as E = Ethical, Ed = Educational, P = Practical, and Ps = Psychological.

No.	Health Evidence	Author(s)	Year	Topic	Country	Journal	Subject
1	M	Nelson et al.	2007	P	USA	*Am J Public Health*	Conceptualizing and defining public health emergency preparedness
2	M	Charania et al.	2011	Ed, P	Canada	*Int J Circumpolar Health*	The 2009 H1N1 pandemic response in remote First Nation communities of Subarctic Ontario: barriers and improvements from a health care services perspective
3	S	Charania et al.	2012	Ed, P	Canada	*BMC Public Health*	A community-based participatory approach and engagement process create culturally appropriate and community informed pandemic plans after the 2009 H1N1 influenza pandemic
4	S	Kim et al.	2012	Ed, Ps	S. Korea	*J Med Intern Res*	Development of a health information technology acceptance model using consumers' health behavior intention
5	S	Cantey et al.	2013	Ed, P	USA	*J Public Health Manag Pract*	Public health emergency preparedness: lessons learned about monitoring of interventions from the National Association of County and City Health Official's survey of nonpharmaceutical interventions for pandemic H1N1
6	M	Rothstein	2015	E, P	USA	*SSRN. Ind Health Law Rev*	Legal and ethical considerations for modern quarantine
7	M	Bachtiger et al.	2020	P, Ps	UK	*medRxiv*	Government policy and reduced willingness to participate in app-based contact tracing
8	S	Joo et al.	2020	Ed, P, Ps	S. Korea	*Service Business*	Resolving the tension between full utilization of contact tracing app services and user stress as an effort to control the COVID-19 pandemic
9	M	Khorram-Manesh et al.	2020	E, P, Ed	Sweden	*Disaster Med Public Health Prep*	Association between welfare, developed infrastructure and prosperity of a country with infectious disease spread
10	M	Alanezi et al.	2020	P, Ed	Saudi Arabia	*J Healthcare Leadership*	A comparative study on the strategies adopted by several countries to contain the spread of the COVID-19 pandemic
11	M	Nazareth et al.	2020	P, Ed	UK	*Lancet*	Early lessons from a second COVID-19 lockdown in Leicester, UK
12	M	Abeler et al.	2020	P, E	UK	*JMIR mHealth uHealth*	COVID-19 contact tracing and data protection
13	M	Hernandez-Quevedo et al.	2020	P, E	European Union	*The Health System Response Monitor*	How do countries structure contact tracing operations and what is the role of apps?
14	M	Du et al.	2020	P, E	China	*JMIR*	COVID-19 contact tracing apps and gaps for international pandemic control
15	S	Korea CDC	2020	P	S. Korea	*Osong Public Health Res*	Contact transmission of COVID-19 in South Korea and novel investigation techniques for tracing contacts
16	M	Rowe et al.	2020	E, P	France	*Eur J Info Sys*	Contact-tracing apps and alienation in the age of COVID-19

Table 1. *Cont.*

No.	Health Evidence	Author(s)	Year	Topic	Country	Journal	Subject
17	S	McGrail et al.	2020	E, P, Ps	Canada	*AJPH*	Contact-tracing apps and broader societal change
18	S	Bernard et al.	2020	E, Ps	UK	*AJPH*	An examination of the rise in government surveillance through mobile applications
19	M	Maghdid et al.	2020	P	Iraq	*SN Computer Science*	A smartphone-enabled approach to manage COVID-19 lockdown and economic crisis
20	M	Li et al.	2020	P	China	*Lancet*	Active case finding and case management: the key to tackling the COVID-19 pandemic
21	S	Guillon et al.	2020	E, Ps	France	*Public Health*	Attitudes and opinions on quarantine and support for a contact-tracing application in France during the COVID-19 outbreak
22	M	Hager et al.	2020	E, P	European Union	*Int Political Sociolog*	Collective discussion: toward critical approaches to intelligence as a social phenomenon
23	M	Abuhammad et al.	2020	E, Ed, P	Jordan	*Patient Preference and Adherence*	COVID-19 contact-tracing technology: acceptability and ethical issues of use
24	M	Reimer et al.	2020	E, P	Australia	*Eur J Info Sys*	Digital contact-tracing adoption in the COVID-19 pandemic
25	M	Basu et al.	2020	E	India	*Camb Quart Healthcare Ethics*	Mobile phones and contact tracing
26	W	Colins	2020	E, P	USA	*Mondaq Bus Brief*	Evolving considerations for multinational employers
27	W	Maati et al.	2020	E, P	Germany	*Czech J Int Relations*	Framing the pandemic and the rise of the digital surveillance state
28	M	Ekong et al.	2020	E, P	Nigeria	*JMIR Mhealth Uhealth*	Mobile positioning data contact tracing and patient privacy regulations
29	M	Dong et al.	2020	E, Ps	China	*J Med Internet Res*	Public emotions and rumors spread during the COVID-19 epidemic
30	S	Sfendla et al.	2020	Ps	Morocco	*Health Secur*	Factors associated with psychological distress and physical activity during the COVID-19 pandemic
31	S	Smith et al.	2020	E, P	UK	*Public Health*	Factors associated with adherence to self-isolation and lockdown measures in the UK: a cross-sectional survey
32	M	Shah et al.	2020	E	Nepal	*Nepal Med Assoc*	Combating the COVID-19 pandemic in Nepal: Ethical challenges in an outbreak
33	M	O'Callaghan et al.	2020	E, P	Ireland	*Ir J Med Sci*	A national survey of attitudes to COVID-19 digital contact tracing in the Republic of Ireland
34	M	Ye	2020	P, Ps	US	*JMIR Pediatr Parent*	Pediatric mental and behavioral health in the period of quarantine and social distancing with COVID-19
35	M	Rothstein	2020	E, P	US	*J Law Med and Ethic*	The coronavirus pandemic: public health and American values.

Table 1. *Cont.*

No.	Health Evidence	Author(s)	Year	Topic	Country	Journal	Subject
36	M	Torous et al.	2020	P, Ps	US	*JMIR Mental Health*	Digital mental health and COVID-19: using technology today to accelerate the curve on access and quality tomorrow
37	S	Tambo et al.	2020	Ed, P	Cameron	*Global Health J*	Early stage risk communication and community engagement (RCCE) strategies and measures against the coronavirus disease 2019 (COVID-19) pandemic crisis
38	W	Simon	2020	E	USA	*Survival*	Subtle connections: pandemic and the authoritarian impulse
39	M	EU	2021	E, P	European Union	*Commissioners' Office Web*	Guide to the general data protection regulation (GDPR)
40	M	Shuja	2021	E	Pakistan	*Applied Intelligence*	COVID-19 open source data sets
41	M	Baumgart et al.	2021	Ed, P	Canada	*NPI Digital Medicine*	Digital advantage in the COVID-19 response: perspective from Canada
42	M	Jacob et al.	2021	P	Canada	*Policy design and practice*	The adoption of contact tracing applications for COVID-19 by the European governments
43	S	Sowmiya et al.	2021	E	India	*SN Computer Science*	A survey on security and privacy issues in contact tracing applications
44	M	Gerli et al.	2021	P	UK	*Government Info Quarterly*	The public value of eHealth application in a pandemic
45	M	Niccolai et al.	2021	P	USA	*AJPH*	Rapid establishment of a volunteer **contact tracing** program for COVID-19
46	M	Thoung et al.	2021	P	Vietnam	*BMJ Global Health*	Public safety and response to the COVID-19 epidemic in Vietnam
47	M	Hassandoust et al.	2021	Ed, P	New Zealand	*JAMIA*	Individuals' privacy concerns and adoption of contact tracing mobile applications in a pandemic
48	S	Bradshaw et al.	2021	Ps	Australia	*Frontiers in Psychology*	The information safety assurance increases intentions to use COVID-19 contact tracing applications
49	M	Legendre et al.	2021	P	Switzerland	*arXiv*	Contact tracing technologies and cyber risks
50	S	CDC	2021	P	USA	*Web*	Contact tracing resources
51	S	Williams et al.	2021	E, Ps	UK	*Health Expectations*	Public attitudes towards COVID-19 contact tracing apps
52	S	Chen et al.	2021	P, Ps	USA	*Geriatr Nurs*	Reactions to COVID-19, information and technology use, and social connectedness among older adults with pre-frailty and frailty

3. Results

The initial term use, Public Health Strategies, returned over 2 million hits in Google Scholar. Similar results were also obtained using other search engines. The search term was changed to "Public Health Strategies" to receive a lower and manageable number of references (Appendix A). Other keywords were added stepwisely, and the number of hits decreased consequently. A descriptive summary of the results from the conducted systematic literature review is presented in Figure 1 in a PRISMA flow chart format. More details regarding the reviewed studies are presented in Table 1, including the following information: (1) health evidence (classified as either Strong (S) or Medium (M) or Weak (W)); (2) author(s); (3) year; (4) journal; and (5) subject of the study. The following four topics were revealed through the content analysis: (1) practical aspects; (2) ethical aspects; (3) psychological aspects; and (4) educational initiatives at the community level. The insights regarding these topics are discussed in the following sections of the manuscript.

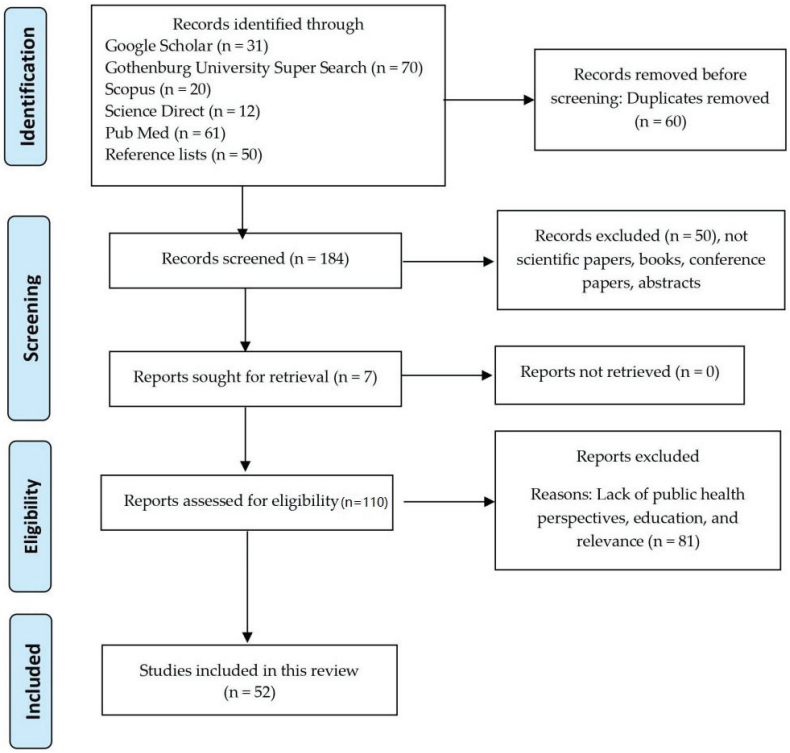

Figure 1. PRISMA 2020 flow diagram for new systematic reviews [44].

3.1. Practical Aspects

A practical app should enable the identification of people who not only belong to the participants' network but also those not known to them, such as fellow passengers on a bus. Working properly, a contact tracing app needs to comply with some technical requirements, of which the most important might be the need to operate at a close range. It is also important that many people use the technology to attain valid and accurate data. Some apps may prompt an individual who may have been in contact with a COVID-19 positive person to self-isolate [48].

Many different technological alternatives were discovered throughout the conducted systematic literature review, including GPS, Bluetooth, cellular location tracking, and QR codes, with a variety of practical and ethical concerns [49,50]. A GPS app, such as the one used in Korea, tracks the movement of people ordered to quarantine. However, the level of accuracy by which it traces contacts is around 10–20 m, which is not effective, particularly inside buildings. The precision of the cellular location data is even lower and poses significant concerns over the privacy of users. Some countries have used the QR

codes to develop surveillance technologies. People are forced to scan their QR code doing certain activities (e.g., shopping, using public transportation) or when they enter into a new country. Although a QR-based system can efficiently control and restrict people's movement, it can neither determine whether there has been any close contact between an infected individual and another person, nor if they obey and follow the rules of social distancing measures in public [49,50].

One promising solution, supported by the EU, is the use of Bluetooth to track the population. One important characteristic of Bluetooth is its ability to operate effectively at a close range. This, in turn, would facilitate the development of an application that allows users to opt-in or out easily by simply turning their Bluetooth on or off. Besides contact tracing, Bluetooth can also hypothetically help to control and measure whether the public respects the guidelines of social distancing. An important characteristic of Bluetooth, in contrast to other forms of cellular data, is its ability to function with an acceptable degree of accuracy at around 2 m. Consequently, its effective administration and utilization would potentially facilitate a faster return to normalcy [8,9,49,50].

Simple and safe technology can contribute to an increased willingness and ability of people to participate and thus increase the reliability and impact of the system. In Sweden, the number of people over 18 years having a smartphone is around 6.7 million. A total of 187,139 people had downloaded the recommended COVID-19 contact tracing app, introduced on April 29 by the end of July 2020 (2.8%) [17], while other countries have reported a higher number of participants (37%). However, these numbers are significantly lower than the recommended 65–70% to cover the necessary area and deliver a reliable result [50].

3.2. Ethical Aspects

Emerging evidence from some EU countries, most affected by the current pandemic, suggests that they use aggregated call detail records (CDRs) to carry out their stay-at-home policies and implementation of lockdowns [4,6,24,51]. In addition, there are other valid ethical concerns regarding the use of contact tracing apps within the EU, challenging its General Data Protection Regulation (GDPR).

According to the GDPR regulation, people have the possibility of using their rights in not disclosing whom they have been in contact with or can legally resist and challenge the tracking by authorities [7,19,22,35]. Furthermore, critics of contact tracing have pointed out that most of the apps are inconsistent with a range of older Android devices. Potentially, this inconsistency jeopardizes and influences the most vulnerable groups since elderly and poor citizens cannot use the new technology and lack the needed financial support to get one. There is also a lack of a mechanism to opt-in or opt-out of the third-party trackers in most used systems.

There has been a discussion regarding the pros and cons of a centralized vs. decentralized data collection system. In a centralized model, the process of matching occurs on a computer server, while in a decentralized model, the exchange takes place on people's devices. Some claim that the relevant authorities will hold the data for a short period and handle it according to the highest ethical and security standards. However, there are reports arguing the necessity of undertaking a transparent Data Protection Impact Assessment (DPIA) before processing any personal data since data needs to be shared because of its nature. According to the EU Data Protection Watchdog, one of the requirements for using a Bluetooth app is to ensure its 'privacy-by-design'. Finally, there is a need for a new legislation to facilitate and safeguard a return to normalcy once the crisis is over to guarantee the public trust enough to consider joining such mass surveillance strategies [7–9,51,52].

3.3. Psychological Aspects

The practical concerns about using apps may also get more complicated with the psychology behind using (or not using) any apps [53–59]. In a recent publication, Williams et al. [53] reported that the participants in their study were not sure whether using digital

contact tracing was a good idea. Their moral reasoning and beliefs strongly influenced their standpoints. There were several themes in their reasoning, such as lack of information and misconceptions around the COVID-19 tracing app, concerns over privacy, stigma, and uptake, and contact tracing as a benefit for the population. These factors, particularly the concerns over privacy, stigma, and uptake, may create a psychological defense barrier for the willingness of using the app. Another Irish study confirmed the results from the UK, although the public willingness to download and use the app in that study was twice as high [53,59].

The use of new technologies and its impact on individuals may differ due to age or underlying medical and psychological conditions, and may include difficulties in the adoption of precautionary measures and altered daily routines. In one study, for instance, although the information and technology use kept the participants informed and connected, they experienced negative emotional consequences, including stress, worry, and anxiety, and reported varying degrees of preparedness [54]. In addition, rumors spread may influence public's emotions, increasing their anxiety and anger [55]. Furthermore, isolation and quarantine during the pandemic seem to be associated with interpersonal sensitivity, somatization, and distress, especially symptoms like suspiciousness, hostility, and fearful thoughts of losing autonomy as well as feelings of inadequacy, uneasiness, and discomfort during interpersonal interactions [56]. All these issues result in poor adherence to self-isolation, contact tracing, and obeying recommendations [57].

3.4. Educational Initiatives at the Community Level

Although there are some variations in rate, over 75% of the populations within different EU countries have downloaded contact tracing apps. It is, however, not clear whether the intent to download corresponds to the actual download and use of the app [59]. Having in mind that information is a necessary part of the implementation process of new ideas and technology, particularly those of global interests, the need for educational initiatives to enable correct understanding of the use and benefits associated with the technologies is undeniable.

Previous studies concerning the 2009 H1N1 pandemic response have indicated that the primary barrier to successful management, besides overcrowding in houses, insufficient human resources, and the lack in local surveillance, is the inadequate community awareness regarding disease processes and prevention [60,61]. Other studies have also shown that adding community specific details, such as information about supplies and resources and details of how, when, where, and who has the responsibility for implementing recommendations outlined in the pandemic plans, together with the roles and responsibilities of the involved organizations, are essential elements in a pandemic plan and guarantee a successful outcome [62]. Irrespective of cultural and traditional background of each community, there have been successful efforts in low- and middle-income countries to engage and mobilize community members in case-detection and reduce the extent of infectious disease by establishing community-based strategies, including workshops and the use of social media [63]. One major facilitator for community engagement today is the use of new technology. Digital approaches, health technologies, and informatics might be used to inform all community members of the scale and development of pandemic, while they may also be designed and implemented to support public health surveillance and critical responses to adults' and children's well-being [64].

While a successful app should have certain grades of quality, security, privacy, defined usability, and compatibility, it is equally important that its need is matched to consumers' general and health literacy levels. Kim and Park presented the concept of the health information technology acceptance model in 2012 (Figure 2) [65]. According to this model, each individual has three concern zones which influence individuals' acceptance of technologies such as contact tracing apps. These are health concerns, information concerns, and technical concerns. All these concerns may influence an individual to accept or deny the use of an application. Within the health zone, the primary factor that influences the use of

the app is how individuals perceive the usefulness of the app to their health. The result of the perceived threats creates a psychological incitement for using the new technology. Within the information zone, there are two primary factors: subjective norms and the technology's credibility. The former is important for behavioral induction and consists of social pressure and community competition, i.e., the signals an individual receives from the surrounding networks about the society's standing in accepting and using the new technology. Therefore, within the health technology, social networking is used to change consumers' behavior and to predict their attitudes. Finally, factors, such as output quality, result demonstrability, objective usability, and perceived enjoyment, all demonstrating technological superiority, result in perceived ease of use and increased motivation for the use of an app [65].

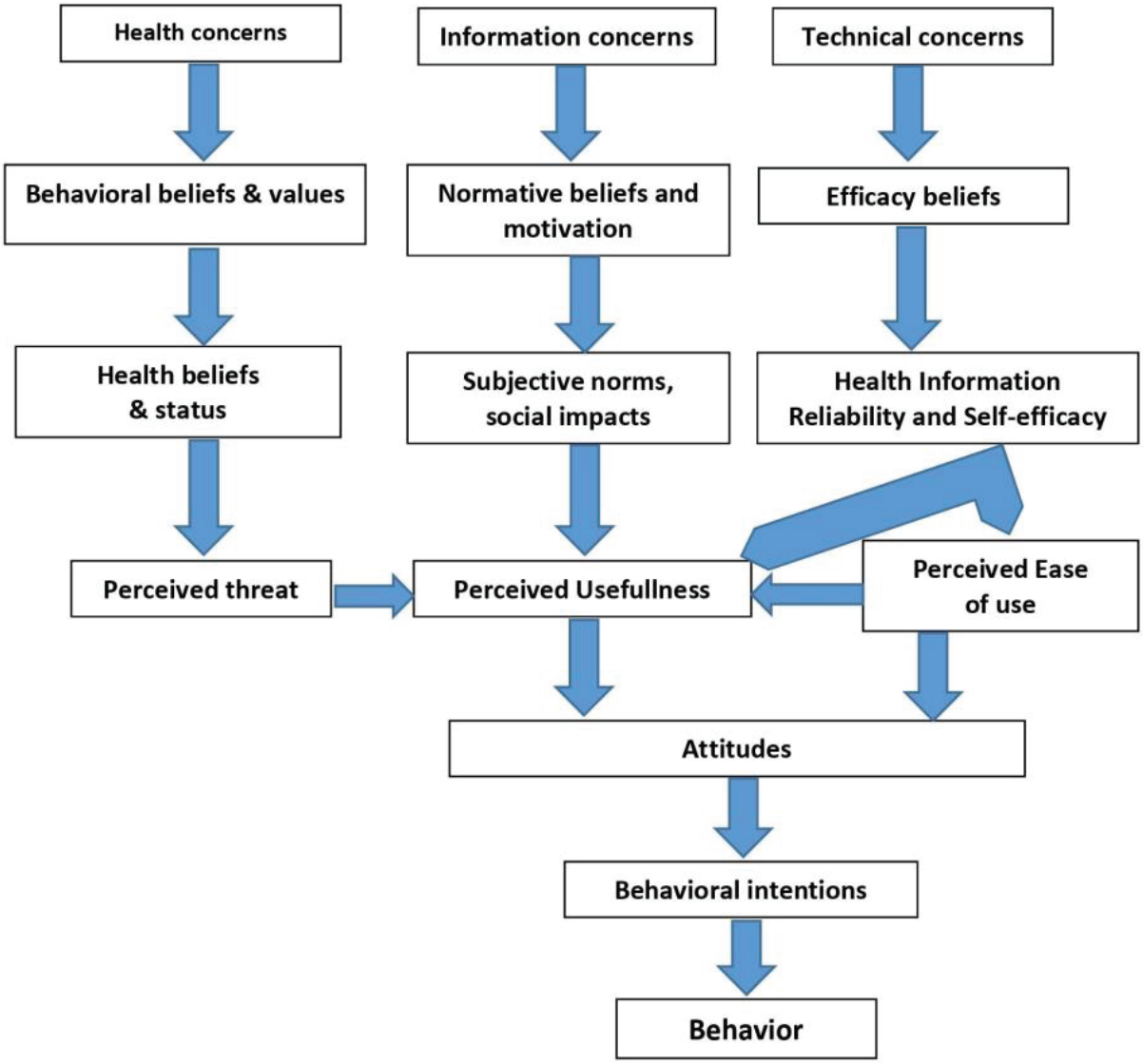

Figure 2. Health information technology acceptance model [65].

4. Discussion

The efficiency of contact tracing in any form depends on the public's willingness to participate and collaborate with the authorities. Such collaboration depends on the trust they have in the government regarding the safety and security measures they impose to protect their private lives and identity. Nowadays, societies with advanced and developed infrastructure are equally affected by the pandemic and might be the first victims [1,3,29–31].

One significant characteristic for these societies is their share in technical instruments and devices utilization. Mobile phones, Bluetooth, GPS, etc. not only enable social networking but also create ethical and psychological dilemmas that need to be discussed if using them as digital public health measures.

The current pandemic manifested at an accelerating rate and created a condition when the lack of specific treatment and vaccine necessitated the implementation of public health strategies. Such strategies may vary due to the cause of outbreak, but in a pandemic, may constitute social distancing, contact tracing, personal protective equipment, isolation, and quarantine [66]. Although the implementation of these strategies might be inevitable, they may create societal and human rights issues, which would yield to inadequate levels of compliance and different outcomes in various nations [12,40]. For instance, the social acceptance of implementing public health strategies has differed between Canada and the USA. The former is known as the home of social solidarity and the latter is known as a nation with rugged individualism, self-reliance, nonconformity, and independence [67]. Although social restrictions might be one of the main reasons for disobeying public health recommendations, other factors, such as housing, transportation, education, employment, food, and other household needs, are all crucial needs of persons under public health surveillance. Addressing these factors will increase individual willingness to comply with voluntary and mandated public health measures such as quarantine [68].

Technical requirements that include opt-in measures are necessary to grant contact tracing app users the ability to return to their normal lives in an achievable time, provided they use the app and respect other important public health measures. This would comply with the European Data Protection Board (EDPB)'s statement that restrictions of freedom during the pandemic or any other emergency during a strictly limited period are acceptable [31,32]. A solely Bluetooth-enabled app would operate on a system of individual anonymous codes, which enables the exchange of codes through a decentralized system. It gives users the most control over their data and should help them prevent the potential privacy conflicts that might arise if governments were to monitor the location data by teaming up with the relevant service providers such as Google. However, the Bluetooth technology still has its limitations.

The current COVID-19 pandemic and the development and deployment of digital public health technologies have initiated efforts to produce scientific and ethical sound guidelines and policies to guarantee personal information safety and ensure widespread public trust and uptake. Since ethical and legal aspects of using such technologies are also main concerns, one measure could be to conduct an ethical–legal analysis of these concepts with procedural considerations in technology governance. Such an approach may result in guidelines, navigation aids, or other algorithms that might help decision makers to ensure procedural validity and minimize ethical issues and shortcomings during the development or deployment of digital public health technologies [33].

Irrespective of all quality controls and information that may eliminate misconceptions, an improvement in psychology and an increase in the understanding of app utilization should be the first steps in using any apps, including contact tracing apps. Moreover, consumers should be educated regarding the content, benefits, and harms of these apps [69,70]. This approach would increase the perceived usefulness and ease of use but also indirectly increase the awareness of individuals in detecting new threats. Several reports have indicated that people with lower health literacy have worse healthcare and poorer health outcomes. They simply lack the skills necessary to manage their health and participate in disease prevention actively [71,72]. Previous studies in different parts of the world have shown that low or limited health literacy in the US, Southeast Asia, and the European Union are prevalent and consistently associated with several factors such as education, ethnicity, and age. In Europe, one in every two Europeans may not be able to comprehend essential health-related information and materials [72–75].

Key components necessary for the preparation of a community to combat emergencies are those of risk communication and community engagement strategies at the early stages.

Preventive and emergency response strategies should be coordinated and strengthened at the community level by improving community resilience and through educational initiatives. The crucial steps in achieving a resilient and knowledgeable community are a transparent and trustful government–people relationship, improved health systems security proactivity, community to individual confinement, trust, and resilient solutions [76,77].

Furthermore, it is equally necessary that those working within the field of information privacy and security accommodate the public demands and protect their rights to privacy. A future public health emergency may not facilitate any option to adopt such mass surveillance measures [32]. It is, thus, crucial to ensure that policies, mathematical models, and technological measures are developed and in place to protect the collected and used data and promote transparency in how data can help contain the spread of disease while protecting and ensuring civil liberties [31].

5. Limitations

The main limitation of this study is its focus on the published literature in English. Consequently, relevant information in other languages may be missing. The criteria used to narrow the selection of included publications enabled the authors to access eligible data and a feasible number of publications to handle the content analysis and to perform the review. However, the criteria used may have been too selective, resulting in missing information. These limitations can be further addressed as a part of the future research.

6. Conclusions

A public health situation becomes an emergency when its scale, timing, or unpredictability have the potential to overwhelm routine capabilities. Such a definition necessitates an all-hazards approach to preparedness, allows for the optimal development of capabilities across scenarios, and better prepares communities for a broad spectrum of potential risks [1,78]. As public health emergencies, in general, and pandemics, in particular, are on the rise, the use of technologies in future communicable diseases might be inevitable. However, it is evident that there are some practical, psychological, and ethical challenges that need to be resolved before future public health policy planning [33]. The implementation of public health strategies, in the absence of appropriate treatment or vaccine, demands higher public health knowledge to recognize, accept, and deal with all restrictions and concerns. Besides educational initiatives at all levels of the society, particularly at the community levels, policy makers should also be prudent in evaluating the risk and benefits of using such technologies while technicians should determine how new generation technologies could be effectively adjusted to increase the public trust when using various technology-based public health strategies in increasing global disorder.

Author Contributions: A.K.-M. provided the main framework, identified, and organized primary materials, and collaborated in writing the manuscript. K.G. identified appropriate references and collaborated on the writing of the manuscript. M.A.D. contributed to drafting sections of the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Datasets used and analyzed during the current study are presented as Appendices A–D.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Searching Procedures

Search Engine	Searching Keywords	Hits
Google Scholar **Reviewed 31 Duplicates 10, Irrelevant 19, Included 12**	Public Health Strategies	>4 million
	"Public Health Strategies"	21,000
	"Public Health emergency" AND [(Contact Tracing) OR (Isolation) OR (Quarantine)]	31,100
	"Public Health emergency" AND "[(Contact Tracing) OR (Isolation) OR (Quarantine)]"	6690
	"Public Health emergency" AND "Contact Tracing" AND "Isolation" AND "Quarantine" AND Public Education	2850
	"Public Health emergency" AND "[(Contact Tracing) OR (Isolation) OR (Quarantine)]" AND "Public Education"	354
	"Public Health emergency" AND "[(Contact Tracing) OR (Isolation) OR (Quarantine)]" AND "Public Education" AND "Community resilience"	31
Gothenburg University Super Search **Reviewed 70 Duplicates 50, Irrelevant 15, Included 7**	"Public Health emergency" AND "Contact Tracing"	2281
	"Public Health emergency" AND "Contact Tracing" AND "Isolation"	1223
	"Public Health emergency" AND "Contact Tracing" AND "Isolation" AND "Quarantine"	803
	"Public Health emergency" AND "Contact Tracing" AND "Isolation" AND "Quarantine" AND Public Education	437
	"Public Health emergency" AND "Contact Tracing" AND "Isolation" AND "Quarantine" AND "Public Education"	70
Science Direct **Reviewed 15, Irrelevant 10, Included 5**	"Public Health emergency" AND [(Contact Tracing) OR (Isolation) OR (Quarantine)]	456
	"Public Health emergency" AND "[(Contact Tracing) OR (Isolation) OR (Quarantine)]"	313
	"Public Health emergency" AND "[(Contact Tracing) OR (Isolation) OR (Quarantine)]" AND Public Education	218
	"Public Health emergency" AND "[(Contact Tracing) OR (Isolation) OR (Quarantine)]" AND "Public Education"	113
	"Public Health emergency" AND "Contact Tracing" AND "Isolation" AND "Quarantine" AND Public Education	15
Scopus **Reviewed 20, Irrelevant 13, Included 8**	"Public Health emergency" AND "Contact Tracing"	286
	"Public Health emergency" AND "Contact Tracing" AND "Isolation"	117
	"Public Health emergency" AND "Contact Tracing" AND "Isolation" AND "Quarantine"	63
	"Public Health emergency" AND "Contact Tracing" AND "Isolation" AND "Quarantine" AND Public Education	20
	"Public Health emergency" AND "Contact Tracing" AND "Isolation" AND "Quarantine" AND "Public Education"	0
PubMed **Reviewed 61, Irrelevant 33, Included 15**	"Public Health emergency" AND [(Contact Tracing) OR (Isolation) OR (Quarantine)]	>2 million
	"Public Health emergency" AND "[(Contact Tracing) OR (Isolation) OR (Quarantine)]"	466
	"Public Health emergency" AND "[(Contact Tracing) OR (Isolation) OR (Quarantine)]" AND Public Education	62
	"Public Health emergency" AND "[(Contact Tracing) OR (Isolation) OR (Quarantine)]" AND "Public Education"	0

Appendix B. PRISMA Checklist Abstract

Section and Topic	Item Number	Checklist Item	Reported (Yes/No)
TITLE			
Title	1	Identify the report as a systematic review.	YES
BACKGROUND			
Objectives	2	Provide an explicit statement of the main objective(s) or question(s) the review addresses.	YES
METHODS			
Eligibility criteria	3	Specify the inclusion and exclusion criteria for the review.	YES
Information sources	4	Specify the information sources (e.g., databases, registers) used to identify studies and the date when each was last searched.	YES
Risk of bias	5	Specify the methods used to assess risk of bias in the included studies.	No
Synthesis of results	6	Specify the methods used to present and synthesise results.	No
RESULTS			
Included studies	7	Give the total number of included studies and participants and summarise relevant characteristics of studies.	No
Synthesis of results	8	Present results for main outcomes, preferably indicating the number of included studies and participants for each. If meta-analysis was done, report the summary estimate and confidence/credible interval. If comparing groups, indicate the direction of the effect (i.e., which group is favoured).	YES
DISCUSSION			
Limitations of evidence	9	Provide a brief summary of the limitations of the evidence included in the review (e.g., study risk of bias, inconsistency and imprecision).	YES
Interpretation	10	Provide a general interpretation of the results and important implications.	No
OTHER			
Funding	11	Specify the primary source of funding for the review.	None
Registration	12	Provide the register name and registration number.	None

From: Page M.J., McKenzie J.E., Bossuyt P.M., Boutron I., Hoffmann T.C., Mulrow C.D., et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi:10.1136/bmj.n71.

Appendix C. PRISMA Checklist Manuscript

Section and Topic	Item Number	Checklist Item	Location Where Item Is Reported
TITLE			
Title	1	**Implementing contact tracing and other public health strategies; needs for educational initiatives—A Systematic Review**	Page 1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Page 1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Page 1–3
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Page 1 & 3
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Method page 2–3
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Method page 2

Section and Topic	Item Number	Checklist Item	Location Where Item Is Reported
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Appendix.
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Method page 2–3
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Method page 2–3
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g., for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Figure 1 page 4, Table 1, page 5
	10b	List and define all other variables for which data were sought (e.g., participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	See point 10a
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Method page 2–3
Effect measures	12	Specify for each outcome the effect measure(s) (e.g., risk ratio, mean difference) used in the synthesis or presentation of results.	NA
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g., tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Result page 3–4
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	NA
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	-
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Method page 2–3
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g., subgroup analysis, meta-regression).	-
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	-
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	-
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Method page 2 HEQAT
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Results, Page 3
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Figure 1
Study characteristics	17	Cite each included study and present its characteristics.	Page 5–7
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	–
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g., confidence/credible interval), ideally using structured tables or plots.	–

Section and Topic	Item Number	Checklist Item	Location Where Item Is Reported
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	–
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g., confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	–
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	–
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	–
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	–
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Table 1, page 5–7
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Page 9–11
	23b	Discuss any limitations of the evidence included in the review.	Page 9–11
	23c	Discuss any limitations of the review processes used.	Page 9–11
	23d	Discuss implications of the results for practice, policy, and future research.	Page 9–11
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Page 11
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Journals homepage
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	–
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	None
Competing interests	26	Declare any competing interests of review authors.	None
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Journals homepage

From: Page M.J., McKenzie J.E., Bossuyt P.M., Boutron I., Hoffmann T.C., Mulrow C.D., et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi:10.1136/bmj.n71. For more information, visit: http://www.prisma-statement.org/ (accessed on 25 April 2021).

Appendix D

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Quality Assessment Tool – Review Articles

Instructions for completion:
Please refer to the attached dictionary for definition of terms and instructions for completing each section. For each criteria, score by placing a check mark in the appropriate box.

First Author: _____
Year: _____
Journal: _____
Reviewer: _____

CRITERIA	YES	NO
Q1. Did the authors have a clearly focused question [population, intervention (strategy), and outcome(s)]?		
Q2. Were appropriate inclusion criteria used to select primary studies?		
Q3. Did the authors describe a search strategy that was comprehensive? *Circle all strategies used*: ▪ health databases ▪ psychological databases ▪ social science databases ▪ educational databases ▪ other ▪ handsearching ▪ key informants ▪ reference lists ▪ unpublished		
Q4. Did search strategy cover an adequate number of years?		
Q5. Did the authors describe the level of evidence in the primary studies included in the review? ▪ Level I → RCTs only ▪ Level II → non-randomized, cohort, case-control ▪ Level III → uncontrolled studies		
Q6. Did the review assess the methodological quality of the primary studies, including: *(Minimum requirement: **4/7** of the following)* ▪ Research design ▪ Study sample ▪ Participation rates ▪ Sources of bias (confounders, respondent bias) ▪ Data collection (measurement of independent/dependent variables) ▪ Follow-up/attrition rates ▪ Data analysis		
Q7. Are the results of the review transparent?		
Q8. Was it appropriate to combine the findings of results across studies?		
Q9. Were appropriate methods used for combining or comparing results across studies?		
Q10. Do the data support the author's interpretation?		
TOTAL SCORE:		

Quality Assessment Rating:	**Strong** (total score 8 – 10)	**Moderate** (total score 5 – 7)	**Weak** (total score 4 or less)

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International Journal of
Environmental Research and Public Health

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Article

Importance of Immediate Electronic-Based Feedback to Enhance Feedback for First-Time CPR Trainees

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Citation: Misztal-Okońska, P.; Goniewicz, K.; Goniewicz, M.; Ranse, J.; Hertelendy, A.J.; Gray, L.; Carlström, E.; Løwe Sørensen, J.; Khorram-Manesh, A. Importance of Immediate Electronic-Based Feedback to Enhance Feedback for First-Time CPR Trainees. *Int. J. Environ. Res. Public Health* **2021**, *18*, 3885. https://doi.org/10.3390/ijerph18083885

Academic Editors: Paul B. Tchounwou, Nicola Magnavita and Aristomenis Exadaktylos

Received: 25 February 2021
Accepted: 6 April 2021
Published: 7 April 2021

Abstract: Sudden cardiac arrest is one of the leading causes of death globally. The recommended clinical management in out-of-hospital cardiac arrest cases is the immediate initiation of high-quality cardiopulmonary resuscitation (CPR). Training mannequins should be combined with technology that provides students with detailed immediate feedback on the quality of CPR performance. This study aimed to verify the impacts of the type of feedback (basic or detailed) the responders receive from the device while learning CPR and how it influences the quality of their performance and the motivation to improve their skills. The study was conducted at the Medical University of Lublin among 694 multi-professional health students during first aid classes on basic life support (BLS). The students first practiced on an adult mannequin with a basic control panel; afterward, the same mannequin was connected to a laptop, ensuring a detailed record of the performed activities through a projector. Next, the participants expressed their subjective opinion on how the feedback provided during the classes, basic vs. detailed, motivated them to improve the quality of their CPR performance. Additionally, during the classes, the instructor conducted an extended observation of students' work and behavior. In the students' opinion, the CPR training with detailed feedback devices provided motivation for learning and improving CPR proficiency than that with a basic control panel. Furthermore, the comments given from devices seemed to be more acceptable to the students, who did not see any bias in the device's evaluation compared to that of the instructor. Detailed device feedback motivates student health practitioners to learn and improve the overall quality of CPR. The use of mannequins that provide detailed feedback during BLS courses can improve survival in out-of-hospital cardiac arrest.

Keywords: first aid; education; basic life support; cardiopulmonary resuscitation; feedback device; simulation; quality; skill retention; motivation; chest recoil; mannequin

1. Introduction

The immediate initiation of cardiopulmonary resuscitation (CPR) by bystanders in an incident is crucial for the survival of patients in cases of out-of-hospital cardiac arrest (OHCA). OHCA is a major health problem in large parts of the world, with an incidence in Europe of 89/100,000 person-years [1]. Although 30 day survival is greatly improved when cardiopulmonary resuscitation (CPR) is performed before the emergency medical service (EMS) arrives, the death rate is still almost 90% [2,3].

The International Consensus on CPR and Emergency Cardiovascular Care Science with Treatment and Recommendations, developed by the International Liaison Committee on Resuscitation (ILCOR), published updated recommendations and guidelines for CPR in 2020 [4]. The authors highlighted evidence that supports the important relationship between quality of CPR and resuscitation outcomes [4,5]. Two key recommendations from the 2020 ILCOR resuscitation guidelines are the use of real-time audiovisual feedback as a means to maintain CPR quality and the importance of early initiation of CPR by bystanders [6].

These findings indicate that, in addition to bystanders' ability to perform CPR, educational quality is also crucial to increasing the chance of survival. In several studies, the authors examined the necessary parameters for effective chest compressions and rescue breaths during CPR training with and without feedback (visual/voice) [7–12]. Parameters such as the correct hand placement, the right frequency of chest compressions, the correct depth of compressions, adequate chest recoil, and the proper time and volume of rescue breaths influence the outcome of successful resuscitation attempts. Consequently, special attention must be paid to students' performance by instructors by providing corrective feedback to help ensure consistency of high-quality performance and to increase the trainees' self-confidence in performing CPR under stressful conditions [13–15].

Previous reviews of the literature have provided good evidence supporting the use of CPR feedback/prompt devices during CPR training to improve CPR skill acquisition and retention [16–18]. These devices are used frequently in clinical practice and are part of an overall strategy to improve the quality of CPR. Their accuracy in measuring some of the aforementioned parameters, such as the compression depth, accommodate for the calibration needed to adjust the stiffness of the support surface upon which CPR is being performed (e.g., floor/mattress).

Currently, simulation mannequins are manufactured with the ability to provide basic and detailed feedback ability. The former uses an indicator lamp to light up different colors to indicate failure or success in student performance, while the latter shows more detailed and instant information such as exact depth of each individual compression or the pace of the performance. Clinical and practical beliefs among instructors of CPR courses, where this study was conducted, favor the use of instant feedback mannequins. However, there is a lack of adequate studies to demonstrate how students rate CPR learning in these two options [17–20]. This study, therefore, aimed to evaluate the perceived feasibility of training on a mannequin with basic and detailed instant feedback [21].

2. Materials and Methods

2.1. Study Design

CPR training began with a theoretical introduction to first aid and CPR. The algorithm for OHCA management in an adult was presented (compliant with the 2015 European Resuscitation Council guidelines) [22]. High-quality CPR was emphasized, and students were familiarized with all the parameters that should be achieved for optimum CPR performance. A demonstration was conducted on an adult Resusci Anne® Skill Reporter™

(New Delhi, India) mannequin from Laerdal Medical with a basic control panel. Afterward, the students practiced CPR on the same mannequin, using the same control panel.

The basic feedback device contained a panel with light-emitting diodes (LEDs) that lit up, informing the students about the following: compression depth level (correct or incorrect), the amount of air during rescue breaths (correct or incorrect), incorrect hand placement for chest compressing (signaled on an image of the chest on the panel), and incorrect airway patency (signaled by the diode placed on the neck shown on the figure indicator).

The feedback received by the basic control panel indicators consisted of lighting up the indicator lamps, where green indicated a well-done activity, while orange and red indicated elements that needed improvement. After connecting the mannequin to the laptop, Skill Reporter™ displayed the exact results of ongoing activities on the monitor screen. Consequently, during chest compression, the student could observe an amplitude graph showing the exact depth of each individual compression and the pace of chest compressions (compressions per minute). During ventilation, the student could observe an amplitude graph showing at what rate air is given and the amount. Students could constantly observe the effects of their actions and incorrect measures at a given moment and try to correct areas of improvement on a regular basis. This detailed feedback gave the opportunity to adjust hand movements to achieve better-quality compressions.

During students' CPR performance, the instructor observed the following: careful hand placement for resuscitation, the quality of chest compressions performed, and the quality of rescue breaths.

2.2. Next Phase

In the next class, the same students continued learning CPR with the same mannequin. However, this time, there was an altered form of feedback. The mannequin was connected to a laptop, from which the indicators of resuscitation were displayed on the screen to the class using a projector. The outcome of the resuscitation was displayed synchronously with a millisecond response time. Figures 1 and 2 present a picture of the feedback screen, as seen by the students.

Figure 1. Detailed record of cardiopulmonary resuscitation (CPR) training in progress displayed on the screen.

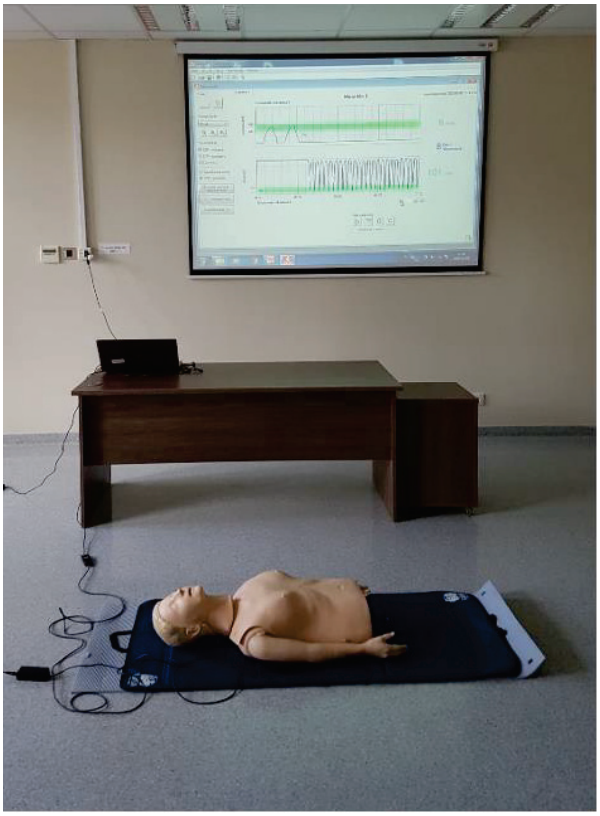

Figure 2. Detailed record of the ongoing CPR displayed on the screen during the research.

A detailed record presented the following:

- Current and average compression rate,
- The exact number of compressions implemented,
- The ratio of the number of chest compressions to the number of rescue breaths,
- Compression depth given in millimeters,
- Relaxation error,
- Hand position error, indicating the direction of the wrong hand position,
- The airway patency,
- The exact amount of air supplied,
- The speed with which the air is introduced during rescue breaths,
- Resuscitation time.

Students were able to observe their performance and correct the quality of CPR activities on an ongoing basis. Moreover, the instructor conducting the classes observed the students and analyzed their behavior during exercises with the device and gave detailed feedback.

2.3. Study Location and Population

The research was conducted from January 2018 to December 2020 at the Medical University of Lublin, Eastern Poland, during first aid classes on basic life support (BLS) in the following faculties: dietetics, cosmetology, physiotherapy, pharmacy, public health, and medical emergency.

All 709 students receiving training participated in the study (100%). After setting aside incomplete questionnaires, 694 students (98%) qualified for further evaluation, of which 416 were from the Faculty of Health Sciences (dietetics, physiotherapy, medical emergency, and public health) and 278 came from the Faculty of Pharmacy (pharmacy and cosmetology).

2.4. Questionnaire

A questionnaire was developed using multiple strategies. First, the authors conducted a literature review to identify the critical dimensions for developing a questionnaire to be used after practical sessions and for the aim of this study. For the review purpose, the following keywords alone or in combination were used: first aid, education, basic life support, cardiopulmonary resuscitation, feedback device, simulation, quality, skill retention, motivation, chest recoil, and mannequins. The acquired data from PUBMED, SCOPUS, and Web of Science were organized, categorized, and mapped to create the questions in the questionnaire. Secondly, a total of nine questions were chosen through the nominal group technique [23] with five students from a local university to evaluate the questionnaire (Appendix A). These participants were later excluded from the study, and their responses were not used in the final analysis. Validity was reviewed on the basis of a combination of logic, relevance, comprehension, legibility, clarity, and usability before the final administration.

2.5. Statistical Analysis

Statistical analysis was performed using SPSS Statistics version 25. A level of $\alpha < 0.05$ was considered statistically significant. Due to the ordinal and nominal nature of the measurement of variables considered essential for the study, nonparametric tests were used. The median, mean, and standard deviation values, percentage distribution, and mean rank were used to describe the obtained results' distribution. The mannequin-dependent score measurements were compared using the Wilcoxon test. Glass's delta expressed the effect size for the calculated difference. The Mann–Whitney U test was used to compare the two groups in terms of the ordinal variable, and the H Kruskal–Wallis test was used to compare more groups. The Mann–Whitney U test was also used as a post hoc test. Its significance level was adjusted using the Bonferroni correction. The effect size for the calculated differences was expressed using Glass's r coefficient and eta-square. Comparing the groups in terms of the qualitative variable was done using the chi-square test, while a Z test with Bonferroni correction was used to compare the columns' proportions. The effect size for the calculated differences was expressed using Cramer's V coefficient.

2.6. Ethics Approval and Consent to Participate

The information included the study's purpose, the voluntary nature of their participation, strict confidentiality, and secure data storage. The survey was anonymous, and all respondents agreed to participate in the survey. Verbal and informed consent was obtained from participants who completed the paper questionnaire. This study complied with the ethical principles stipulated by Polish law and, thus, was exempt from ethics approval requirements by a named institutional and/or licensing committee.

3. Results

The average age of the respondents was 20.89 years, with a standard deviation of 1.54. The youngest respondent was 19 years old, and the oldest was 30 years old. The most frequent age group was 19 years old, accounting for 29.80% of all respondents. The second-largest group was the group of respondents aged 20 (28.00%), and the third-largest group was aged 21 (19.60%). More detailed data on the characteristics of the studied group are presented in Table 1.

Table 1. Characteristics of the researched group.

Faculty	*n*	%	M (%)	Female	Male
Dietetics II year	136	20	21.33	124	12
Dietetics IV year	30	4	23.12	29	1
Pharmacy I year	105	15	20.08	87	18
Pharmacy IV year	41	6	23.04	29	12
Physiotherapy I year	118	17	19.48	76	42
Cosmetology I year	132	19	19.19	132	0
Public Health II year	51	7	20.29	43	8
Medical Rescue I year	81	12	20.67	26	55
Total	**694**	**100**	**20.89**	**552**	**157**

Figure 3 presents the distribution of the answers given by the respondents according to the degree of students' motivation to learn. On an 11-point scale, subjects marked both types of feedback, separately for classes with basic and detailed feedback devices, providing their opinion on their motivation to practice CPR. A closer answer to 10 denoted higher motivation to work with the given feedback, while values close to 0 indicated no such motivation.

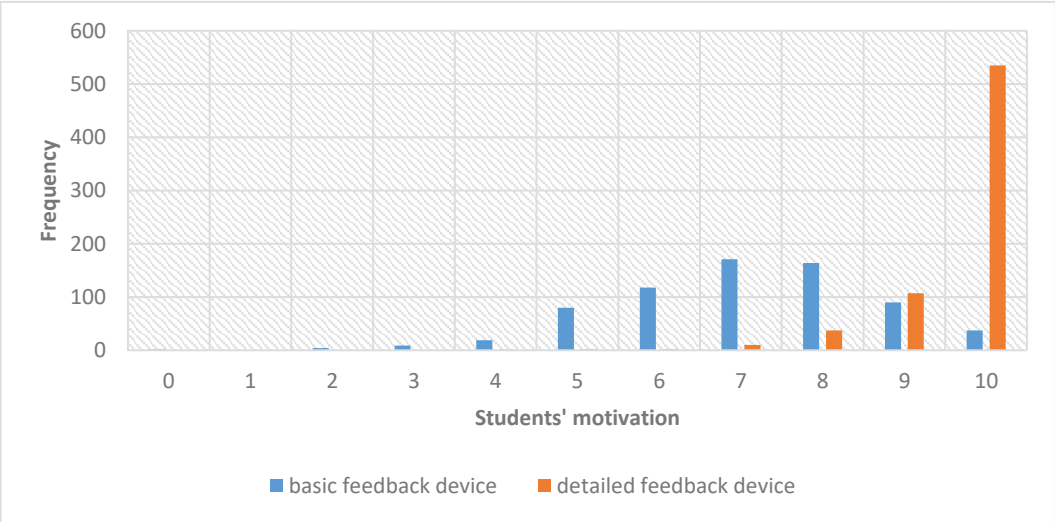

Figure 3. Feedback assessment depending on its type.

The respondents scored the assessed detailed feedback significantly higher than the basic one, as shown by the Wilcoxon test ($Z = 21.941$; $p < 0.001$, $r_g = 0.832$). The median score for high-fidelity mannequins was 10 (Me = 10), while the median score for low-fidelity mannequins was 7 (Me = 7). The H Kruskal–Wallis test was used to investigate the relationship between the respondents studying in different faculties and the feedback assessment. The test showed statistically significant yet minute differences between the abovementioned groups of respondents in the assessment of basic feedback ($\chi^2 = 27.594$; $p < 0.001$; $\eta^2 = 0.027$) and detailed feedback ($\chi^2 = 25.175$; $p = 0.001$; $\eta^2 = 0.024$). The medians of the results obtained by the groups of respondents and the post hoc tests carried out in pairs to examine the differences in detail are presented in Table 2.

Table 2. Mannequin assessment depending on the respondents' group.

Feedback Type	Faculty	M	*n*	Me	Pharmacy IV Year	Dietetics IV Year	Dietetics II Year	Medical Rescue I Year	Physiotherapy I Year	Public Health II Year	Pharmacy I Year
basic	Cosmetology I year	372.33	132	7	2404.5	1761.0	8152.5	5286.5	6328.5	3154.5	5147.5 *
	Pharmacy IV year	335.59	41	7		469.0	2529.5	1475.5	2191.0	853.0	1785.5
	Dietetics IV year	412.63	30	8			1746.0	1113.0	1225.0	730.0	962.0 *
	Dietetics II year	365.82	136	7				5340.0	6607.5	3165.5	5336.5 *
	Medical Rescue I year	372.43	81	7					3954.0	1962.5	3265.0
	Physiotherapy I year	306.33	118	7						2242.5	5813.0
	Public Health II year	395.00	51	7							1796.0 **
	Pharmacy I year	282.58	105	7							
detailed	Cosmetology I year	333.42	132	10	2266.0	1782.5	8402.5	4994.0	7374.5	2985.5	5844.5
	Pharmacy IV year	278.71	41	10		461.5	2160.5	1513.0	1905.5	766.5	1493.0 **
	Dietetics IV year	367.92	30	10			1960.5	1023.5	1685.0	755.5	1490.0
	Dietetics II year	355.14	136	10				4811.0	7942.0	3290.5	6456.5
	Medical Rescue I year	311.65	81	10					4225.5	1710.0	3351.0 *
	Physiotherapy I year	351.60	118	10						2826.0	5548.5
	Public Health II year	372.41	51	10							2563.0
	Pharmacy I year	387.27	105	10							

* $p < 0.05$; ** $p < 0.01$; M—average rank; *n*—number; Me—median.

The observed differences were statistically significant in assessing the basic feedback device in the view of respondents from pharmacy and those from public health, dietetics (second and fourth year), and cosmetology.

Respondents studying pharmacy assessed the detailed feedback device statistically higher compared to the respondents studying the combination of emergency medical services and pharmacy.

Figure 4 shows the difference between the high-fidelity mannequin and the low-fidelity mannequin scores. Negative results indicate a better response to the high-fidelity mannequin, and positive results indicate a better response to the low-fidelity one.

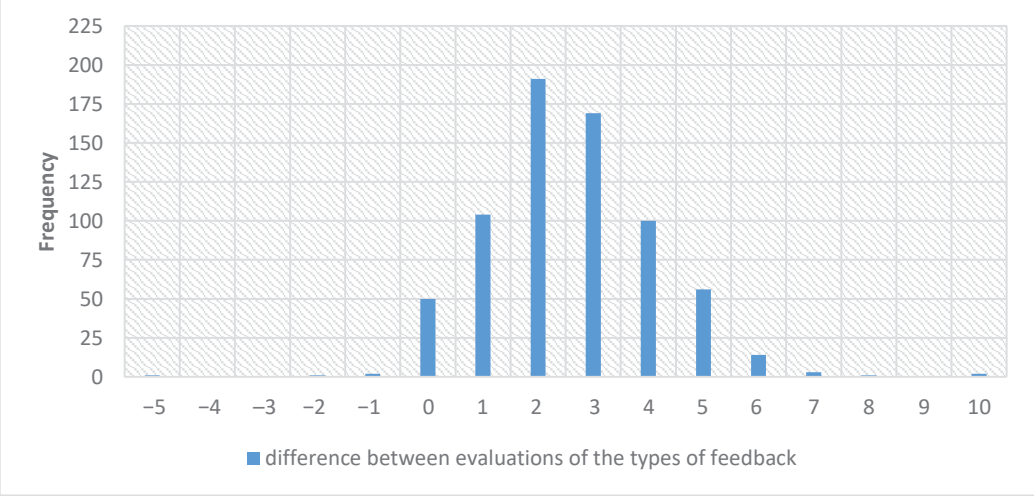

Figure 4. The difference between the high-fidelity mannequin and the low-fidelity mannequin scores.

The vast majority of respondents, as shown above, assessed detailed feedback higher than the basic one. Only four (0.6%) respondents rated the basic feedback higher than the detailed feedback device. A small number of respondents (n = 50; 7.2%) did not notice any difference between the two types of feedback.

Three groups of respondents divided according to the scheme above (lower ratings for detailed feedback, the same assessment for both feedback types, higher ratings for detailed feedback) were compared in terms of response to displaying their CPR outcomes on the projector (in the group) and in terms of self-assessment of their CPR ability. Analysis conducted using the chi-square test showed a statistically significant albeit weak relationship between the assessment of the feedback type and the reaction to displaying respondents' outcomes on the projector in the presence of the group (χ^2 = 24.061; $p < 0.001$; V = 0.132) (Table 3). However, no correlation was found between the difference in the assessment of feedback types and the overall self-assessment of CPR skills (Kruskal–Wallis test = 2.489; p = 0.288). The median self-assessment of the ability to provide CPR in the group of respondents who rated the basic feedback higher was 3.50 (Me = 3.50), while the median in the group of respondents who assessed the detailed feedback higher and assessed them both at the same level was 4 (Me = 4).

Table 3. Distribution of the feedback type by the respondents and the reaction to displaying their outcomes on a projector in the presence of their group.

Students' Reaction to Displaying Their Outcomes on a Projector	*n*	Feedback Preferences		
		Basic Feedback	No Preference	Detailed Feedback
Adverse—embarrassment	*n*	2 $_{a}$	0 $_{b}$	27 $_{b}$
	%	50.00%	0.00%	4.22%
Positive—motivation increase	*n*	2 $_{a}$	43 $_{a}$	551 $_{a}$
	%	50.00%	86.00%	86.09%
Neutral	*n*	0 $_{a}$	7 $_{a}$	62 $_{a}$
	%	0.00%	14.00%	9.69%

Each subscript letter represents a subset of the feedback preference category whose column proportions do not differ significantly (by 0.05).

Comparing the proportions of the columns using the Z test showed that the respondents who preferred the basic feedback, more often than the respondents preferring the detailed feedback or those without the preference, experienced adverse embarrassment to the presentation of their outcomes on the projector.

The next stage of the analysis was to answer the question of whether the belief about which type of feedback should be used in CPR classes is related to the fear of displaying the subject's outcomes on the projector in front of the entire group and to the self-assessment of one's own CPR abilities. The Mann–Whitney U test (U = 12,045.00; p = 0.257) and the chi-square test (χ^2 = 0.404; p = 0.816) did not reveal any statistically significant relationships between the abovementioned variables. The median self-assessment of one's abilities, both in the group of respondents who believed that classes should be conducted with a basic feedback device and in the group of respondents who believed that a detailed feedback device is best suited, was 4 (Me = 4). The distribution of respondents' responses to displaying their outcomes on the projector is presented in Table 4.

Table 4. Distribution of basic and detailed feedback devices in conducting CPR classes and the reaction to displaying their work on a projector in the presence of a group.

Students' Reaction to Displaying Their Outcomes on a Projector	*n*	The Belief in the Usefulness of the Given Feedback	
		Highest Usefulness of Basic Feedback Device	Highest Usefulness of Detailed Feedback Device
Adverse—embarrassment	*n*	2 $_{a}$	27 $_{a}$
	%	5.00%	4.13%
Positive—motivation increase	*n*	33 $_{a}$	563 $_{a}$
	%	82.50%	86.09%
Neutral	*n*	5 $_{a}$	64 $_{a}$
	%	12.50%	9.79%

Each subscript letter represents a subset of the feedback preference category whose column proportions do not differ significantly (by 0.05).

In the group of respondents who believed that it was more reasonable to use a basic feedback device during CPR practice, 5% declared experiencing negative emotions when their actions were displayed on a projector, and 12.5% reported a neutral attitude. In comparison, 82.5% experienced an increase in motivation in such a situation of social exposure. In the group of respondents who believed that it was more appropriate to use the detailed feedback device during CPR classes, 4.13% reported experiencing negative emotions when their actions were displayed on a projector, while 9.79% reported a neutral attitude toward it. In comparison, 86.09% experienced an increase in motivation in this situation.

There was no significant difference in the BLS management algorithm's knowledge, regardless of the used feedback method. Minor errors in sequencing the procedure or forgetting some activities happened when using either a basic or a more detailed feedback tool. However, a significant difference was observed in students who practiced with a detailed feedback device. The students strived more to achieve high quality concerning both chest compressions and rescue breaths than when working with a basic feedback device.

Moreover, receiving information about mistakes made was better received by students when the information came from the device than from the instructor. Students accepted corrective instruction from the computer program record and found it more objective compared to the instructor. In situations where corrective action was recommended by the instructor, some students interpreted this as instructor bias against the student and viewed this as unjustified criticism. More than once, students tried to contest a negative comment, questioning and failing to accept it, or requesting the instructor to give a higher grade by disputing error occurrence. Conversely, the device's result was not subject to discussion on the student's part; it was accepted, and the students understood improvement was required.

4. Discussion

The World Health Organization aims to empower communities during disasters and emergencies [24–27]. First aid and CPR skill training contribute to community preparedness and resilience and should be widely available [28]. There is scientific evidence that introducing lay BLS courses improved survival rates 30 days and 1 year after sudden cardiac arrest [29,30]. Given the positive response from student health professionals, to improve skill acquisition and retention in BLS courses for health and laypeople, detailed feedback should be provided during all CPR training. In particular, high-fidelity device training that provides instant feedback should be available to students pursuing health professions in terms of training and careers, as well as laypeople who are obliged to provide first aid, e.g., teachers, medical guardians, security guards, and police officers. From a cognitive perspective, learning during training signifies an individual's capacity to obtain and reflect on external information to apply it in real-life scenarios [31–35]. To optimize feasibility, there needs to be a constructive alignment between learning goals and learning

activities [36]. All students have different ways of learning. As Hattie discovered, students have additional attributes, prior knowledge, motivations, and intentions to participate in learning, thus leading to significant variance [37].

According to this study, students learning with mannequins that provided instant and accurate feedback were more engaged and motivated to have the best-quality CPR result. These results were statistically significant regardless of the participants' field of study, with the vast majority of students highlighting that their CPR practice should be based on mannequins providing detailed feedback (94.2%).

Most often, students had prior experience with basic mannequins that made a sound or showed a light when pressed, with a basic control panel and no feedback. As a result, their actions were often rated very high or entirely correct, and the students were, thus, convinced that CPR was very simple to perform. However, after using the mannequin with detailed feedback, the students realized that they did not achieve the recommended depth of compressions, usually compressed too quickly, had problems with proper airway patency, and gave far too little or too much air during rescue breaths. In accordance with other studies receiving detailed feedback from the device, this enabled them to improve their CPR results to as high as 100% [38–40]. Students practiced on the mannequin willingly; students (mostly male students) asked to be allowed to test/retest their abilities many times. This willingness to practice allowed the students to measure the time in which their activities resulted in effective resuscitation until the quality of their actions clearly decreased. On the first day of the class, when the exercises were performed on the mannequin with a basic control panel, the students performed CPR less willingly, without significant engagement. Eshel et al. reached similar conclusions when comparing the CPR quality performed on two student groups [41]. One class (the control group) was taught using standard mannequin-based CPR models. The second class (the intervention group) was taught similarly but with real-time CPR quality feedback. In multiple regression analysis, the real-time feedback group results were significantly better than the control group in all baseline scores, adjusted to the participant's age, gender, and body mass index characteristics [35]. Another study similar to the present report was conducted by Lu et al., in which the authors verified whether a smartwatch with real-time feedback could improve the quality of CPR performed by healthcare professionals [42]. It showed that, without real-time feedback, chest compressions were usually too fast and too shallow, and that CPR quality could be improved with a smartwatch that provides real-time feedback [43]. Tanaka et al. conducted a randomized, controlled trial to compare standard CPR training (control) and QCPR Classroom (intervention) amongst 642 Japanese students over 15 years of age. As in this study, QCPR Classroom participants could see their CPR results on a large screen, while the control group only received subjective instructor feedback. QCPR Classroom was found to help students obtain high-quality CPR training, especially in terms of correct compression depth and full recoil [44]. Other research studying the influence of received feedback on CPR quality [45,46] reported similar conclusions.

During the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2; COVID-19) pandemic, the provision of mouth-to-mouth rescue breaths by lay people is not recommended due to the risk of transmission of infection [47]. Therefore, the focus should be on high-quality chest compressions [48]. A study by Stiell et al. proved the importance of chest compressions quality during CPR. A study of patients with prehospital sudden cardiac arrest demonstrated that increased compression depth in CPR is strongly associated with better survival [49]. Maximum survival was in the depth range of 40.3 to 55.3 mm (peak, 45.6 mm) [50]. However, in this study, approximately 20% of participants showed a lack of full chest expansion during CPR, claiming that that no one had previously informed them about the significance and possibility of this error. As noted in the European Resuscitation Council (ERC) 2015 guidelines, it is often found that the rescuer's hands rest on the chest during CPR such that the return to its original shape is incomplete [51], while a full chest recoil after each compression results in a better return of venous blood to the chest, which may improve CPR effectiveness [52].

In this study, the authors recognize that the students better perceived receiving information about mistakes when the information came from the device than from the instructor. Another argument in favor of introducing accurate feedback devices can be derived from the exciting results of the research by Hansen et al., who investigated whether BLS instructors correctly assess medical students' CPR skills [52]. They found that certified BLS instructors rated the CPR abilities of participants poorly. Of the 90 CPR assessments conducted by 16 pairs of instructors, 90% passed the exam (81 students), while the mannequin pass rate was only 2% [52]. Other authors have also come to similar conclusions [53–57].

Another interesting result of this study was the outcome of participants' self-assessment of CPR skills. All students assessed themselves very similarly, regardless of whether they were students of emergency medical services, whose profession would involve performing medical rescue activities, or students of other faculties, e.g., cosmetology or public health. Students did not rate themselves highly; most of them rated their skills as 4 on a five-point Likert scale, indicating a high awareness of their deficits and the need for regular practice and recall of CPR procedures. It can be concluded, after the class using a mannequin with detailed feedback, that students were aware that not everything was performed correctly. They observed that it was not easy to maintain the correct pace of compressions or maintain an appropriate depth; hence, they approached self-assessment critically and objectively. According to their assessment, they somehow demonstrated that the highest rating (5) requires regular exercise. The only similar study that we could refer to when comparing our results was the study by Abolfotouh et al., who verified, among other things, the importance of mental attitude in respondents toward CPR [58]. A positive attitude was significantly more often shown, in statistical terms, by participants who recently completed BLS training, had a higher number of previous BLS training sessions, and/or had earlier exposure to cardiac arrest, which means that, with more experience, self-confidence, and self-esteem, one's abilities increase.

5. Limitations

This study has some limitations. This was a convenience sample from one university. Accordingly, a lack of medical students from the medical faculty participated because the emergency department does not conduct CPR classes for them. This study could be performed with two groups (control and study) to further evaluate the differences. The outcome of this study indicates a need for further controlled studies with a larger sample. This study may also initiate a discussion on this subject and the perspective of broader research in this area. The experience gained from this study can form the basis for planned future research, comparing training methods in other countries globally, thereby providing a wider standardization of the research tool used.

6. Conclusions

This study found that detailed feedback provided via training mannequins increases participants' motivation to learn and improve their CPR proficiency. Devices that provide detailed feedback during BLS courses may contribute to improving overall CPR quality, increasing the chances of survival in cases of OHCA. Providing detailed feedback concerning CPR provider performance in the presence of other students may be an effective motivator to improve or correct technique.

Author Contributions: P.M.-O. provided the main framework, identified and organized primary materials, and collaborated in writing the manuscript. K.G. identified appropriate references and collaborated in writing the manuscript. M.G. was involved in data analysis, interpreted the results, and collaborated in writing the manuscript. J.R., A.J.H., L.G., E.C. and J.L.S. contributed to drafting sections of the manuscript. A.K.-M. collaborated in writing and editing the paper. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

The Questionnaire

Please read the questionnaire carefully and fill it in. When answering, please tick the appropriate boxes. The survey is completely anonymous. Your responses will only be used for statistical summaries.

1. **How would you rate your motivation to learn CPR on a simple mannequin that gives green- or red-light feedback (good/bad)? Did you have a strong desire to improve your skills while practicing on this mannequin?**

   I have no motivation 1 2 3 4 5 6 7 8 9 10 I have motivation

2. **How do you evaluate your motivation to learn CPR on a high-fidelity mannequin that provides detailed projector feedback on a large screen? While learning on this mannequin, did you have a strong desire to improve your skills?**

   I have no motivation 1 2 3 4 5 6 7 8 9 10 I have motivation

3. **Did it bother you that the effect of your work was displayed on the projector screen or did it motivate you to work better?**

- It bothered me, it intimidated me
- It motivated me to work better, to improve my skills
- It did not bother me or motivate me
- Other

4. **How would you rate your CPR skills overall?**

   Very low 1 2 3 4 5 6 7 8 9 10 Very Good

5. **Do you think simple low-fidelity mannequins are sufficient to teach first aid as part of your field of study or should classes be taught on high-fidelity mannequins with advanced feedback?**

- Simple low-fidelity phantoms are sufficient
- Classes should be conducted on high-fidelity phantoms with detailed feedback

6. **Faculty**

- Dietetics
- Physiotherapy
- Cosmetology
- Medical Rescue
- Other

7. **Year of study**

- First
- Second
- Third

8. **Gender**

- Male
- Female

9. **Age**

- 19
- 20

- 21
- 22
- 23
- 24
- Other

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International Journal of
Environmental Research and Public Health

MDPI

Article

A Cross-Sectional Study on the Flood Emergency Preparedness among Healthcare Providers in Saudi Arabia

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Citation: Al-Wathinani, A.M.; Alakeel, A.; Alani, A.H.; Alharbi, M.; Almutairi, A.; Alonaizi, T.; Alhazmi, R.A.; Alghadeer, S.M.; Mobrad, A.M.; Goniewicz, K.; et al. A Cross-Sectional Study on the Flood Emergency Preparedness among Healthcare Providers in Saudi Arabia. *Int. J. Environ. Res. Public Health* **2021**, *18*, 1329. https://doi.org/10.3390/ijerph18031329

Academic Editor: José Carmelo Adsuar
Received: 20 October 2020
Accepted: 28 January 2021
Published: 2 February 2021

Abstract: This study used a descriptive cross-sectional methodology to measure healthcare workers' knowledge, attitudes, perceptions, and willingness to respond to a flood scenario in Saudi Arabia. A validated survey was distributed to collect data using a convenience sampling technique through multiple social media platforms. A total of 227 participants were included in this study: 52% of them were aged between 26 to 34 years, 74% were residents from Riyadh, and 52.4% worked in nursing divisions. A significant number of respondents (73.2%) had positive perceptions towards their hospitals' ability to provide an effective response to a flood, 89% were willing to report to work following a flood, and 90% of participants reported the need to develop both guidelines and training for flood disaster preparedness. Preparation and successful flood mitigation in the hospital setting requires staff that have both knowledge and training in emergency management. One way to obtain such readiness is through competency-based training, including both table-top and full-scale live exercises. Although the willingness to respond to such a flooding emergency was high among staff, the development of guidelines and educational programs is needed in order to develop the competencies and skills sets to improve disaster preparedness response and preparedness efforts.

Keywords: flood; disasters; emergency preparedness; hospital preparedness; Saudi Arabia

1. Introduction

Morbidity and mortality attributed to flooding can either be caused directly by drowning, electrical shock injuries, and the transmission of communicable diseases, or indirectly

by affecting infrastructure or other essential necessities of life and the interruption of fundamental public health services [1]. Floods can, in general, be categorized into either flash flood events or associated with cyclones, tsunamis, or storm surges [1]. As a result of global warming, climate change has also increased the risk of floods [2]. According to the Organization for Economic Cooperation and Development, the global cost of floods is approximately 40 billion USD per annum [3]. This type of natural hazard is projected to raise the global burden of disease, morbidity, mortality, and social and economic instability and place continued stress on healthcare systems [4].

Saudi Arabia (SA) is a disaster-prone country. Flooding, although infrequent, has posed significant challenges in the past [5]. The country has reported 14 floods that have impacted approximately 30,000 citizens and resulted in economic losses of about $450 million during the last three decades [5]. Examples include Makkah's 2003 flood, which was the worst in the past 25 years [6]. Then in 2004, Jizan had experienced one of the most devastating floods in 45 years. Widespread devastation was reported during Medina's flood in 2005. Jeddah's floods occurred in 2009 and 2011, which resulted in 172 deaths [7]. In the capital city, Riyadh, floods in 2005 and 2010 resulted in numerous deaths and forced others to evacuate [6]. The frequency of flood occurrences in SA is expected to be at least seven times per year on average, mainly during the winter, and affecting all regions of the country [7–9]. Additionally, projected rainfall trends during 2025–2044, 2045–2064, and 2065–2084 based on data coming from the National Center for Atmospheric Research (NCAR) Community Climate System Model (CCSM4) have showed variable patterns, with significant increases in certain regions of SA [10]. It was reported that hospitals in Jeddah had faced a major crisis in 2009 as a result of the aforementioned floods. It raised many concerns at the Ministry of Health (MOH) and with other authorities about the preparedness of hospitals in SA [8].

The healthcare infrastructure in SA is managed by the MOH. Services are made available to the public through a network of 244 hospitals and 2037 primary healthcare centers across the country [6]. However, other governmental agencies also provide healthcare services independently of the MOH. These include the Ministry of Defense and Aviation (MODA), the Ministry of Education (MOE), the Saudi Arabian National Guard (SANG), the Ministry of the Interior (MOI), and the Red Crescent Society [6].

The Presidency of Meteorology and Environment is responsible for disaster risk reduction efforts in SA, and the Civil Defense at the MOI is responsible for emergency planning and response [6,9]. The current disaster risk management paradigm does not utilize a coordinated multi-agency level response approach. Instead, practice remains unconventional and subject to regional variations [11,12]. Alshehri and colleagues surveyed the public in Saudi Arabia, where a majority believed that God is in control of the world, and that disasters may be considered as punishment by God for transgressions by mankind [13]. The study recommended a focus on public awareness in terms of education, training, and volunteering in an effort to improve disaster readiness in the country [12]. Another study by Abosuliman et al. emphasized the need for the identification and coordination of organizational responsibilities and advocated for response team training [14]. Finally, a recent study by Al-Shareef et al. suggested that some hospitals might be inadequately prepared for future disasters in SA [15]. These studies show a significant shortcoming in response capabilities and civilian preparedness.

Floods are considered a major disaster in SA with the potential to disrupt the lives of residents, businesses, and critical government infrastructure, such as hospitals [6]. Flood-related disruptions may come in many different forms. For instance, Thailand's 2011 flood resulted in many damaged hospitals, unavailability and/or disruption of supply chains, and staff shortages [16]. Several studies have reported an unwillingness of healthcare workers to return to work following a disaster, in addition to a general lack of knowledge related to disaster preparedness and response [17–19]. While there is a strong health system operating in SA, improvements are needed in localized and appropriate disaster-related training and investments in workforce education in order to strengthen flood resilience.

The aim of this study was to evaluate healthcare workers' (HCWs) knowledge, attitudes, and perceptions of their preparedness and willingness to respond properly during future flood disasters in the Kingdom of Saudi Arabia.

2. Materials and Methods

2.1. Study Design

A descriptive, cross-sectional study design that measured HCWs' willingness to respond, knowledge levels, attitudes, and perceptions with regard to a flood scenario at their hospital was utilized. Ethical approval was obtained from the Institutional Review Board at King Saud University Medical City. Informed consent was completed electronically. Only anonymous data were kept and shared with the study team. Participants who agreed to give their consent were included in the analysis. The study took place in SA between December 2019 and April 2020.

2.2. Variables

Independent variables included in this study were age, gender, marital status, number of residing children, type of occupation, years of service within the hospital, and the scope of hospital practice, (governmental vs. private). Dependent variables consisted of general knowledge and perceptions towards floods, willingness to report to work following a disaster, and knowledge concerning a flood scenario.

2.3. Sample Size

According to published data from the McKinsey Global Institute, the total number of males and females working in the healthcare sector in SA in 2014 was 600,000, with 350,000 healthcare professionals and 250,000 management and other support staff [20]. To facilitate the identification of differences and similarities, and to illustrate the complexity of this issue between the participants regarding each section of the survey, it was estimated that 196 participants were needed, while fixing the marginal error to 7% and a 95% confidence interval.

2.4. Enrolment

The study participants were HCWs of both genders who were working and living in SA. The process of enrolment was completed anonymously and voluntarily. Data was collected using a convenience sampling technique. To reach our target population, the survey was disseminated electronically using various social media platforms (WhatsApp, Telegram, Twitter, and Instagram) targeting groups and accounts known to be an aggregate of healthcare professionals where information around continuing medical education activities are shared [21]. The link to the survey was shared over a period of 14 days.

2.5. Data Collection Tools and Procedures

A recently developed and validated tool to model HCWs' willingness to respond to an earthquake scenario was used in this study by changing the scenario to flooding. This survey initially aimed to measure HCWs' willingness to respond to a variety of emergency situations. Previous studies have described in detail the design and validation process [16,17]. The flooding scenario was adopted as it is the country's most common natural catastrophe, causing 7 out of 10 of the most devastating natural disasters in the history of SA between 1900 and 2010 [9], and because certain regions of the country are also projected to experience future trends of increased precipitation and extreme rainfall events [10].

The final version of the survey is composed of 34 items. The data collection tool is divided into two sections: one for the demographic information of participants, and the other measures knowledge and perceptions. The latter section contains questions related to HCWs and perceptions towards their roles following a flood, knowledge, competency, and willingness to report to work in the event of a flood scenario, and the factors that

may influence their decisions in such circumstances. Lastly, participants were also asked about their perceptions in terms of guideline development and training sessions on flood disasters. The final questionnaire's presentation, in terms of feasibility, readability, accuracy, design and formatting, and quality of the vocabulary used, was subjected to face validity checks with 10 volunteer experts from King Saud University Medical City. An Arabic version was available, which was translated by two authors and piloted on the same volunteers for validation. A scoring system was developed for knowledge questions: it considers zero to three correct answers as a low level of knowledge, four to seven correct answers as a moderate level of knowledge, and eight to twelve correct answers as a high level of knowledge.

2.6. Data Analysis

All data analyses were performed using International Business Machines (IBM, Armonk, NY, USA) Statistical Package for the Social Sciences (SPSS) 20.0 software (SPSS Inc., Chicago, IL, USA). Demographic data was analyzed and presented using frequencies and percentages. General levels of knowledge and perceptions towards flood disasters was also analyzed and presented using percentages and frequencies, followed by independent sample *t*-test. Lastly, responses regarding the willingness to report to work following a flood in addition to those related to the knowledge and competency concerning the flood scenario were analyzed using independent sample *t*-tests. Chi-square test was used for statistical testing and the significance was set to be less than 0.05.

3. Results

3.1. Demographic Characteristics

A total of 227 HCWs participated in this survey. The demographic characteristics can be found in Table 1. Males accounted for 77% of participants, with females accounting for 23%. Almost half of the total of participants (52%) belonged to the 26- to 34-year-old age group. Nearly one-third (29.1%) had 6 to 10 years of service, followed by 24.2% who had 2 to 5 years of service. A majority (94.7%) reported to work in the governmental sector. The highest numbers of participants were in Riyadh (74%) and married (65.6%). Meanwhile, 72.2% reported living with children. Approximately, half of the participants reported working in nursing divisions (52.4%), and nursing as a profession accounted for (40.1%).

Table 1. Demographic characteristics of the participants.

	Groups	Female (*n* = 53)	Male (*n* = 174)	All (*n* = 227)
Age	18–25 years	13 (24.5)	28 (16.1)	41 (18.1)
	26–34 years	24 (45.3)	94 (54)	118 (52)
	35–44 years	12 (22.6)	44 (25.3)	56 (24.7)
	45 and above	4 (7.5)	8 (4.6)	12 (5.3)
Length of Service	Less than 1	11 (20.8)	26 (14.9)	37 (16.3)
	2–5 years	19 (35.8)	36 (20.7)	55 (24.2)
	6–10 years	9 (17)	57 (32.8)	66 (29.1)
	11–15 years	8 (15.1)	40 (23)	48 (21.1)
	16–20 years	2 (3.8)	10 (5.7)	12 (5.3)
	20+ years	4 (7.5)	5 (2.9)	9 (4)
Scope of Hospital Practice	Private	1 (1.9)	9 (5.2)	10 (4.4)
	Government	52 (98.1)	163 (93.7)	215 (94.7)

Table 1. *Cont.*

	Groups	Female (*n* = 53)	Male (*n* = 174)	All (*n* = 227)
Place of Residence	Riyadh	41 (77.4)	127 (73)	168 (74)
	Eastern Region	3 (5.7)	2 (1.1)	5 (2.2)
	Makkah	0 (0)	8 (4.6)	11 (2.2)
	Madinah	3 (5.7)	11 (6.3)	11 (4.8)
	Qassim	1 (1.9)	17 (9.8)	19 (8.4)
	Southern Region	3 (5.7)	2 (1.1)	3 (1.3)
	Northern Boarders	3 (0.6)	5 (2.9)	8 (3.5)
Family Status	Single	29 (54.7)	49 (28.2)	78 (34.4)
	Married	24 (45.3)	125 (71.8)	149 (65.6)
Number of Children	No Children	20 (37.7)	43 (24.7)	63 (27.8)
	1	11 (20.8)	37 (21.3)	48 (21.1)
	2	9 (17)	37 (21.3)	46 (20.3)
	3	5 (9.4)	29 (16.7)	34 (15)
	3+	8 (15.1)	28 (16.1)	36 (15.9)
Department	Nursing	40 (75.5)	79 (45.4)	119 (52.4)
	Physician	5 (9.4)	10 (5.7)	15 (6.6)
	Paramedic	0 (0)	15 (8.6)	18 (7.9)
	Pharmacy	3 (5.7)	15 (8.6)	15 (6.6)
	Other Clinical	2 (3.8)	41 (23.6)	43 (18.9)
	Support Services	0 (0)	9 (5.2)	9 (4)
	Fiscal and Administrative	3 (5.7)	5 (2.9)	8 (3.5)
Discipline	Nursing	26 (49.1)	65 (37.4)	91 (40.1)
	Physicians	15 (28.3)	18 (10.3)	33 (14.5)
	Pharmacy	3 (5.7)	14 (8)	17 (7.5)
	Administrative Professional/Secretary	2 (3.8)	11 (6.3)	13 (5.7)
	Other	7 (13.2)	66 (37.9)	73 (32.2)

Data are expressed as *n* (%).

3.2. Knowledge and Perceptions

In Table 2, an independent sample *t*-test was performed on gender for items related to participants' perceptions towards their roles following a flood. Results demonstrated a significant statistical difference in the item related to familiarity with roles within the hospital's operations following a flood ($p < 0.01$)—mean 3.44 ± 1.29 for males vs. 2.83 ± 1.26 for females. Due to a high percentage of those agreeing to the provided statements related to their roles following a flood, no significant differences were found. Furthermore, in perceptions related to the knowledge and competency concerning a presumed flood scenario, a statistically significant difference was found between males and females in terms of familiarity with the hospital's standard operating procedure ($p < 0.01$)—mean 3.12 ± 1.33 for males vs. 2.57 ± 1.16 for females. Another significant difference was found related to male HCW confidence in managing a flood scenario ($p < 0.05$)—mean 3.32 ± 1.31 for males vs. 2.91 ± 1.26 for females. No other significant differences were detected ($p > 0.05$).

Table 2. Knowledge and perceptions of participants.

		Knowledge and Perceptions as *n* (%)					*p*-Value (Independent Sample *t*-Test)
		Strongly Disagree	**Disagree**	**Impartial**	**Agree**	**Strongly Agree**	
Perceptions of the Role Following a Flood							
My role is vital to my organization's effective management of a flood	Female	6 (11.3)	3 (5.7)	6 (11.3)	19 (35.8)	19 (35.8)	0.171
	Male	7 (4)	9 (5.2)	18 (10.3)	72 (41.4)	68 (39.1)	
	All *	13 (5.7)	12 (5.3)	24 (10.6)	91 (40.1)	87 (38.3)	
The hospital is prepared to provide an effective response to a flood	Female	4 (7.5)	1 (1.9)	12 (22.6)	26 (49.1)	10 (18.9)	0.478
	Male	8 (4.6)	22 (12.6)	14 (8)	79 (45.4)	51 (29.3)	
	All *	12 (5.3)	23 (10.1)	26 (11.5)	105 (46.3)	61 (26.9)	
I am familiar with my role in the hospital's operation following a flood	Female	12 (22.6)	8 (15.1)	13 (24.5)	17 (32.1)	3 (5.7)	0.003
	Male	18 (10.3)	32 (18.4)	17 (9.8)	69 (39.7)	38 (21.8)	
	All *	30 (13.2)	40 (17.6)	30 (13.2)	86 (37.9)	41 (18.1)	
Perceptions of Knowledge and Competency Concerning a Flood Scenario							
I have sufficient knowledge concerning the treatment of flood victims	Female	8 (15.1)	14 (26.4)	8 (15.1)	19 (35.8)	4 (7.5)	0.068
	Male	24 (13.8)	28 (16.1)	20 (11.5)	73 (42)	29 (16.7)	
	All *	32 (14.1)	42 (18.5)	28 (12.3)	92 (40.5)	33 (14.5)	
I am familiar with the hospital's standard operating procedure for floods	Female	12 (22.6)	15 (28.3)	11 (20.8)	14 (26.4)	1 (1.9)	0.007
	Male	29 (16.7)	36 (20.7)	16 (9.2)	71 (40.8)	22 (12.6)	
	All *	41 (18.1)	51 (22.5)	27 (11.9)	85 (37.4)	23 (10.1)	
I feel safe to stay at the hospital if a flood occurs	Female	9 (17)	10 (18.9)	7 (13.2)	19 (35.8)	8 (15.1)	0.468
	Male	26 (14.9)	24 (13.8)	25 (14.4)	73 (42)	26 (14.9)	
	All *	35 (15.4)	34 (15)	32 (14.1)	92 (40.5)	34 (15)	
I feel that I am competent as a caregiver to manage a flood	Female	12 (22.6)	7 (13.2)	9 (17)	24 (45.3)	1 (1.9)	0.043
	Male	22 (12.6)	31 (17.8)	23 (13.2)	65 (37.4)	33 (19)	
	All *	34 (15)	38 (16.7)	32 (14.1)	89 (39.2)	34 (15)	

Data are expressed as *n* (%); *: Both genders.

In Table 3, we report the results of independent sample *t*-tests to detect gender differences in the willingness to report to work after a flood; no statistically significant difference was reported ($p > 0.05$). However, when factors influencing the decision to report to work following a flood scenario was considered, a significant difference was found in females' concerns for their families' wellbeing ($p < 0.01$)—mean 4.89 $\pm$ 0.47 for females vs. 4.60 $\pm$ 1.04 for males. A statistically significant difference was found among females regarding concerns of houses being damaged as a consequence of the flood ($p < 0.05$)—mean 4.68 $\pm$ 0.78 for females vs. 4.34 $\pm$ 1.17 for males. With regards to professional commitment to care for the injured or ill victims, a statistical difference was found, with females having a higher commitment ($p < 0.05$)—mean 4.81 $\pm$ 0.56 for females versus 4.59 $\pm$ 1.03 for males.

Another statistically significant difference was found in Table 4 with regard to females' perceptions towards the need for the development of guidelines for flood disasters and subsequent training in flood response ($p < 0.05$).

As reported in Appendix A, an average of three questions out of twelve were answered correctly for questions testing the knowledge and competency of the HCWs (range = 5.3% to 53.7%; mean = 25.4%; median = 21.6%). The highest percentages of correct answers per question were reported for responses regarding appropriate actions to be taken for a severely injured person, what is to be considered when an anxiety-stricken patient presents to the hospital, and the authority of issuing an evacuation of a department/unit (53.7%, 52%, and 38.3%, respectively). In contrast, the least correctly answered questions were reported for the questions regarding appropriate actions for a lightly injured casualty, the appropriate method of communications in the case of a shutdown, and the recommended treatment protocol for a casualty suffering from a crush injury (5.3%, 7.5%, and 14.1%, respectively). No significant associations were detected between the given answers and genders ($p > 0.05$).

Interpretation of the knowledge level score created by the authors can be found in Table 5. The answers provided by the participants indicate that almost all of them have low and moderate perceived knowledge levels (99.6%). Additionally, results showed that more than half of the participants scored a low knowledge level (60.8%) followed by a moderate knowledge level (38.8%). Only a single subject (0.4%) scored a high knowledge level, therefore it is not presented in the table. Chi-square test results demonstrated no associations between the level of knowledge and all the demographic information collected ($p > 0.05$).

Table 3. Factors influencing decisions and willingness to report to work after floods.

		Willingness to Report to Work Following a Flood—Opinion as *n* (%)					*p*-Value (Independent Sample *t*-Test)
		No, I Don't Believe I/They Will Show Up	The Chances Are Low	I Can't Decide	Yes, Almost Positive	Yes, without a Doubt	
Will you report to work immediately after a flood?	Female	1 (1.9)	2 (3.8)	2 (3.8)	12 (22.6)	36 (67.9)	0.915
	Male	4 (2.3)	5 (2.9)	11 (6.3)	35 (20.1)	119 (68.4)	
	All ***	5 (2.2)	7 (3.1)	13 (5.7)	47 (20.7)	155 (68.3)	
In your opinion, will your colleagues report to work immediately after a flood?	Female	1 (1.9)	2 (3.8)	9 (17)	14 (26.4)	27 (50.9)	0.581
	Male	5 (2.9)	7 (4)	15 (8.6)	52 (29.9)	95 (54.6)	
	All ***	6 (2.6)	9 (4)	24 (10.6)	66 (29.1)	122 (53.7)	
		Factors Influencing Decision to Report to Work Following a Flood—Opinion as *n* (%)					*p*-value (Independent Sample *t*-test)
		Not at All	To a Small Extent	To an Undefinable Extent	To a Medium Extent	To a Large Extent	
Concern for my family's wellbeing	Female	0 (0)	1 (1.9)	0 (0)	0 (0)	49 (92.5)	0.006 **
	Male	9 (5.2)	5 (2.9)	3 (1.7)	12 (6.9)	145 (83.3)	
	All ***	9 (4)	6 (2.6)	3 (1.3)	15 (6.6)	194 (85.5)	
Concern that my house will be damaged in the flood	Female	0 (0)	3 (5.7)	1 (1.9)	6 (11.3)	43 (81.1)	0.018 *
	Male	8 (4.6)	14 (8)	9 (5.2)	22 (12.6)	121 (69.5)	
	All ***	8 (3.5)	17 (7.5)	10 (4.4)	28 (12.3)	164 (72.2)	
Professional commitment to care for the injured or ill	Female	0 (0)	1 (1.9)	1 (1.9)	5 (9.4)	46 (86.8)	0.038 *
	Male	6 (3.4)	8 (4.6)	6 (3.4)	12 (6.9)	142 (81.6)	
	All ***	6 (2.6)	9 (4)	7 (3.1)	17 (7.5)	188 (82.8)	
Fear of losing my place of employment due to my absence	Female	10 (18.9)	9 (17)	5 (9.4)	9 (17)	20 (37.7)	0.870
	Male	37 (21.3)	27 (15.5)	14 (8)	18 (10.3)	78 (44.8)	
	All ***	47 (20.7)	36 (15)	19 (8.4)	27 (11.9)	98 (43.2)	

***: Both genders; **: Significant at level 0.01; *: Significant at level 0.05.

Table 4. Perception towards guidelines development and training sessions.

		Developing a Guideline for Flood Disasters Accompanied with Training Sessions for Hospital Staff—Opinion as *n* (%)					*p*-Value (Independent Sample *t*-Test)
		Not at All	To a Small Extent	To an Undefinable Extent	To a Medium Extent	To a Large Extent	
Developing guidelines for flood disasters	Female	0 (0)	2 (3.8)	1 (1.9)	4 (7.5)	46 (86.8)	0.036 **
	Male	4 (2.3)	7 (4)	7 (4)	31 (17.8)	125 (71.8)	
	Total ***	4 (1.8)	9 (4)	8 (3.5)	35 (15.4)	171 (75.3)	
Attending training sessions on how to manage flood disasters	Female	0 (0)	3 (5.7)	0 (0)	2 (3.8)	48 (90.6)	0.021 *
	Male	7 (4)	10 (5.7)	5 (2.9)	20 (11.5)	132 (75.9)	
	Total ***	7 (3.1)	13 (5.7)	5 (2.2)	22 (9.7)	180 (79.3)	

*** Both genders; **: Significant at level 0.01; *: Significant at level 0.05.

Table 5. Level of knowledge and competency concerning a flood.

		Knowledge Level as *n* (%) §		
	Groups	Low (*n* = 138)	Moderate (*n* = 88)	*p*-Value (Chi-Square Test)
Gender	Male	105 (46.5%)	68 (30.1)	0.485
	Female	33 (14.6%)	20 (8.8)	
	Total **	138 (61.5%)	88 (38.9)	
Age	18–25 years	22 (9.7%)	19 (8.4)	0.166
	26–34 years	72 (31.9%)	46 (20.4)	
	35–44 years	39 (17.3%)	16 (7.1)	
	45 and above	5 (2.2%)	7 (3.1)	
	Total **	138 (61.1%)	88 (38.9%)	
Length of Service	Less than 1	21(9.3%)	16 (7.1%)	0.531
	2–5	36 (15.9%)	19(8.4%)	
	6–10	38 (16.8%)	27 (11.9%)	
	11–15	33 (14.6%)	15 (6.6%)	
	16–20	5 (2.2%)	7 (3.1%)	
	20+ years	5 (2.2%)	4 (1.8%)	
	Total **	138 (61%)	88 (38.9%)	
Type of Hospital	Private	7 (3.1%)	3 (1.3%)	0.409
	Government	130 (58%)	84 (37.5%)	
	Total **	137 (60.6%)	87 (38.4%)	
Place of Residence	Riyadh	97 (43.3%)	70 (31.3%)	0.471
	Eastern Region	3 (1.3%)	2 (0.9%)	
	Makkah	8 (3.6%)	3 (1.3%)	
	Madinah	7 (3.1%)	4 (1.8%)	
	Qassim	12 (5.4%)	7 (3.1%)	
	Southern Region	3 (1.3%)	0 (0%)	
	Northern Boarders	7 (3.1%)	1 (0.4%)	
	Total **	137 (60.6%)	87 (38.4%)	

Table 5. *Cont.*

		Knowledge Level as *n* (%) §		
	Groups	**Low (*n* = 138)**	**Moderate (*n* = 88)**	***p*-Value (Chi-Square Test)**
Family Status	Single	43 (19%)	34 (15%)	0.156
	Married	95 (42%)	54 (23.9%)	
	Total **	138 (61%)	88 (38.9%)	
Number of Children	0	38 (16.8%)	24 (10.6%)	0.690
	1	29 (12.8%)	19 (8.4%)	
	2	32 (14.2%)	14 (6.2%)	
	3	19 (8.4%)	15 (6.6%)	
	3+	20 (8.8%)	16 (7.1%)	
	Total **	138 (61%)	88 (38.9%)	
The Department of Workplace	Nursing	74 (32.7%)	44 (19.5%)	0.262
	Physician	10 (4.4%)	5 (2.2%)	
	Paramedic	5 (2.2%)	10 (4.4%)	
	Pharmacy	13 (5.8%)	5 (2.2%)	
	Other Clinical	24 (10.6%)	19 (8.4%)	
	Support Services	7 (3.1%)	2 (0.9%)	
	Fiscal and Administrative	5(2.2%)	3 (1.3%)	
	Total **	138 (61%)	88 (38.9%)	
Discipline	Nursing	51 (22.6%)	39 (17.3%)	0.148
	Physicians	25 (11.1%)	8 (3.5%)	
	Pharmacy	13 (5.8%)	4 (1.8%)	
	Other	49 (21.7%)	37 (16.4%)	
Total *	226 **	138 (61%)	88 (38.9%)	

§: The only single high knowledge score subject was excluded from the analysis of the Chi-square test to avoid statistical errors. *: Total number of participants with low and moderate knowledge scores. **: Both genders.

4. Discussion

This study assessed flood disaster preparedness among HCWs by measuring knowledge, attitudes, perceptions, and willingness to respond after a flood scenario. Nearly three-quarters of participants (73.2%) believed that hospitals are prepared to provide an effective response. Although many men had claimed to be familiar with their roles in the hospital's operation following a flood, only 56% among all respondents actually felt that they were familiar with their roles following a disaster flood scenario. In parallel, women were reported to be less confident, but perhaps had more realistic views about flooding risks in Saudi Arabia. Though multi-agency collaboration has long been a good base for disaster management, good collaboration between organizations requires a common understanding of their emergency response responsibilities and organizational frameworks [22]. It is expected that if all stakeholders took part in a well-designed and practiced inter-agency all-hazards emergency response, HCWs at multiple hospitals would be more likely to have more faith in their expertise, skills, and competence [23]. Thus, through a case study in Saudi Arabia, it is suggested that the principle of collaboration and its implementation in disaster management should be revisited within the country.

In a cross-sectional survey conducted in the United States (US), results suggested that the majority of HCWs expected to be provided personal protective equipment as well as other measures to ensure hospital staff safety following a disaster [24,25]. Notably,

94% of the US study participants were confident about their hospitals' abilities to respond effectively, with non-clinical staff found to be more confident when compared to clinical staff (OR 1.43, 95 % CI: 1.15–1.78) [25]. These findings are in contrast with results of a previous study, which reported high awareness among emergency physicians and nurses in SA [25]. In a local study, a large number of participants (85.7%) were confident in terms of their ability to handle disasters in a large tertiary hospital [25]. This discrepancy may be explained due to the nature of the study sample, which enrolled only emergency department staff [26,27].

When the flood scenario was proposed in this study, 45% of men believed that they were more familiar with the hospital's standard operating procedures. Findings related to perceptions of knowledge and competency revealed that approximately 55% of all participants felt confident in the ability to treat flood victims. Concerns for personal safety, such as the hospital's infrastructure being able to withstand a flood, was reported by 44.5% of participants. An Australian study also reported concerns among HCWs when asked about their personal preparedness. The study reported negative responses among non-emergency nursing staff and physiotherapists. Only a limited number of staff were capable of identifying their roles during a disaster response [28]. The findings in this study have identified a high number of HCWs (89%) who were willing to report to work immediately after a flood. The former percentage dropped slightly when the same surveyed staff were asked about expectations regarding their colleagues and peers (82.8%). Therefore, a low percentage of absenteeism could be expected. However, fear of losing jobs due to absence from work was a prevalent opinion among 55.1% of respondents. It is important to note that a higher percentage of respondents were working in nursing divisions (52.4%), a profession known to be dominated by expatriates in SA [29].

Conversely, an analysis of 2864 responses from an online survey of HCWs in the United States reported safety concerns as the most frequently cited barrier preventing workers from returning to work after an influenza pandemic, or any other disaster involving contagion or contamination [29]. The authors have acknowledged that studies concerned with workforce absenteeism during disasters is increasing, but in general remain an underrepresented issue in emergency planning efforts [30]. Quershi reported that 81% of 6628 HCWs from 47 healthcare facilities in New York City and the surrounding areas were willing to report to work during an environmental disaster [31]. Findings of the Quershi study were consistent with our results.

In this study, females were found to be more committed to reporting to work ($p < 0.05$) as well as more concerned for the wellbeing of their families ($p < 0.01$) and towards their houses sustaining damage due to a flood ($p < 0.05$). In a study by Cone and Cummings [29], data from 1711 respondents revealed that 87% were willing to work after mass casualty events, mainly in the case of natural disasters, but were less willing to return to work if a man-made catastrophe was suggested. While workers in such man-made incidents should not be endangered, disaster planners should consider that reassurance and assistance for HCWs may need to be handled differently. Several studies suggest that fears of one's own safety, concern for the wellbeing of loved-ones, childcare, and other issues were linked to the failure of healthcare professionals to report for duty during crisis [31].

The need for developing flood disaster guidelines, accompanied with relevant training sessions of hospital staff, was a popular opinion for 90% of all participants—-statistical significance was found among females ($p < 0.05$). The need for such guidance related to flood preparedness has been previously documented in other studies [32–35].

The hospital staff response was analyzed in terms of personal protective measures, case management/referral, and communication and competency skills listed in the protocols, policies, and procedures. Results of the flood scenario illustrated a surprising low percentage of correct answers, as stated previously. The scoring system from the checklist revealed that 99.6% of all HCWs demonstrated low to moderate levels of competency. Chi-square test results revealed no associations with the collected demographic information ($p > 0.05$). Our findings were consistent with a similar study in SA conducted

solely on nurses that reported a lack of knowledge in regard to disaster and emergency preparedness [36].

To our best knowledge, this is the first study to assess flood disaster preparedness and the willingness to respond among healthcare workers in SA.

Findings of this study revealed multiple significant differences among the independent variables. Thus, it is believed that these findings can serve as a foundation for describing the current situation in the central region of SA.

5. Limitations

A limitation of this study is the potential for misclassification bias. This might be due to the adopted questionnaire being designed to measure disasters preparedness for an earthquake scenario. Nevertheless, key aspects of providing healthcare services during these responses are generally shared among natural disasters, and mainly affected by the management of assets, human resources, victims' management and referral, mental health regulations, inter-agency collaboration, technology, information, communication, budget, and training management [37]. Another potential bias could be related to participants' previous exposure and experiences with floods in the past. Geographic representation of the sample is considered to be another limitation, since participants represented mainly the central region of SA. While the current study demonstrated a lack of preparedness for flooding, further studies on all hazard emergencies preparedness might be of limited value due to the nature of disasters in the Saudi context [21].

6. Conclusions

The study demonstrated that levels of preparation for flood disaster management among healthcare providers in Saudi Arabia is inadequate for effective flood disaster responses. Our findings suggest that a majority of HCWs are confident of their hospitals' preparedness to provide an effective response during flood disasters that is in line with the knowledge or theory side. Nevertheless, most of the participants (99.6%) demonstrated low and moderate levels of competency towards flood emergency preparedness due to the climate and geographical location of the kingdom. It is also estimated that a high percentage of HCWs are willing to report to work following a flood. Expected factors influencing the decision to report to work following a flood were concerns for their families' wellbeing, as well as towards the security of their houses. Our study is consistent with the results in the literature, demonstrating the shortcomings related to preparedness and training for an actual flooding disaster [38]. While future training on general disaster response and preparedness and command center activities to enhance the collaborations between stakeholders seems to be crucial, additional areas of improvement needed for managing the impacts of future episodes of floods requires the development of national preparedness and training guidelines for hospitals in SA, including full-scale disaster exercises to measure the effectiveness of preparedness and response [39–42]. Directions for future research should focus on the differences in terms of preparedness among hospitals belonging to governmental sectors (MOH, MOE, MODA, MOI, and SANG) in order to tailor training programs according to regional- and/or hospital-specific contexts and needs, and should also direct additional focus on all hazard responses, command center operations, and communications [43–47].

Flooding today must be both appreciated and managed as multifactorial events [48–52]. Therefore, developing guidelines and standard operating procedures in addition to the introduction of educational interventions, such as training campaigns, and designing mobile solutions aimed to enhance the knowledge and awareness among HCWs is highly recommended [53–67]. It is essential to make a major shift toward improvement as far as the notion of flood disaster preparedness for healthcare providers is concerned. This study contributes to a fuller understanding of the needs of Saudi healthcare workers and may aid in their better planning for future flood disasters.

Author Contributions: Conceptualization: A.M.A.-W.; methodology: A.M.A.-W. and A.A. (Abdulaziz Alakeel); software: R.A.A. and S.M.A.; validation: R.A.A. and A.A. (Abdulaziz Alakeel); formal analysis: A.M.M., S.M.A., and R.A.A.; investigation: A.M.M. and S.M.A.; resources: A.A. (Abdullah Almutairi), M.A., A.M.M., and T.A.; data curation: A.A. (Abdullah Almutairi), M.A., A.M.M., and T.A.; writing—original draft preparation: A.M.A.-W. and A.H.A.; writing—review and editing: A.J.H., K.G., and A.K.-M.; visualization: K.G. and A.K.-M.; supervision: A.J.H.; project administration: A.M.A.-W. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Acknowledgments: The authors extend their appreciation to the Deanship of Scientific Research at King Saud University for funding this work through Research Group no RG-1440-134.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Questions and answers regarding knowledge and competency concerning a flood scenario.

Question	Correct Answers as *n* (%)				*p*-Value (Chi-Square Test)
	Categories	Female (*n* = 53)	Male (*n* = 174)	All (*n* = 227)	
What are the protection measures that should be provided for immobile patients during a flood?	Evacuate the patient with his/her bed to an external site outside the department [a]	13 (24.5)	58 (33.3)	71 (31.3)	0.529
	Evacuate the patient with his/her bed to the departmental protected area	20 (37.7)	58 (33.3)	78 (34.4)	
	There is no way to protect immobile patients	1 (1.9)	5 (2.9)	6 (2.6)	
	Protect the patients in their beds by placing items under their beds to raise height of beds	6 (11.3)	10 (5.7)	16 (7)	
	I don't know	13 (24.5)	43 (24.7)	56 (24.7)	
What are the personal protective actions the staff must implement during a flood?	Exit the department into the stairway all the way to the roof.	18 (34)	38 (21.8)	56 (24.7)	0.392
	Depart externally, outside of the hospital's structure.	5 (9.4)	24 (13.8)	29 (12.8)	
	Avoid working alone and wear a coast guard-approved life jacket/vest [a]	7 (13.2)	34 (19.5)	41 (18.1)	
	Wear a coast guard-approved life jacket/vest and avoid floodwater areas.	6 (11.3)	30 (17.2)	36 (15.9)	
	Dependent on the floor you are present in during the flood	15 (28.3)	41 (23.6)	56 (24.7)	
	I don't know	2 (3.8)	7 (4)	9 (4)	

Table A1. *Cont.*

Question	Correct Answers as *n* (%)				*p*-Value (Chi-Square Test)
	Categories	Female (*n* = 53)	Male (*n* = 174)	All (*n* = 227)	
According to the standard operating procedure, what are the immediate actions to be implemented immediately following a flood?	Immediate evacuation of all patients from the department	14 (26.4)	53 (30.5)	67 (29.5)	0.128
	Identification of hospital's departments that were damaged and provision of assistance as needed [a]	5 (9.4)	40 (23)	45 (19.8)	
	Scout the area to locate casualties and damage	13 (24.5)	33 (19)	46 (20.3)	
	Concentrate staff and patients in the department and wait for instructions from the hospital management	4 (7.5)	13 (7.5)	17 (7.5)	
	I don't know	17 (32.1)	35 (20.1)	52 (22.9)	
In case of potential damage to gas pipes and/or electricity supply infrastructure, what security measures should be implemented?	An immediate evacuation of the department	19 (35.8)	65 (37.4)	84 (37)	0.849
	The electricity, water, and gas supplies should be disconnected immediately	15 (28.3)	51 (29.3)	66 (29.1)	
	A substitute electricity source should be applied (a generator) [a]	7 (13.2)	26 (14.9)	33 (14.5)	
	No action should be taken	0 (0)	2 (1.1)	2 (0.9)	
	I don't know	12 (22.6)	30 (17.2)	42 (18.5)	
Who is authorized to issue an evacuation of a department/unit?	The hospital's management solely	10 (18.9)	41 (23.6)	51 (22.5)	0.061
	The hospital's management [a]	15 (28.3)	72 (41.4)	87 (38.3)	
	The most senior member of the department	2 (3.8)	13 (7.5)	15 (.6)	
	The head of the department	11 (20.8)	18 (10.3)	29 (12.8)	
	I don't know	15 (28.3)	30 (17.2)	45 (19.8)	

Table A1. *Cont.*

Question	Correct Answers as *n* (%)				*p*-Value (Chi-Square Test)
	Categories	**Female (*n* = 53)**	**Male (*n* = 174)**	**All (*n* = 227)**	
What medical registration procedures apply regarding admittance of patients to the hospital following a flood?	The routine medical registration will be continued	7 (13.2)	19 (10.9)	26 (11.5)	0.837
	Manual registration will be applied, and a list of casualties will be transferred [a]	12 (22.6)	50 (28.7)	62 (27.3)	
	A small card will be utilized for every patient stating basic details and diagnosis	12 (22.6)	33 (19)	45 (19.8)	
	In an emergency situation, there is no time for an organized medical registration	6 (11.3)	25 (14.4)	31 (13.7)	
	I don't know	16 (30.2)	47 (27)	63 (27.8)	
What is the recommended treatment protocol for a casualty suffering from a crush syndrome upon arrival at the hospital?	Amputation of the wounded limb	3 (5.7)	11 (6.3)	14 (6.2)	0.596
	Fasciotomy and extensive debridement of the necrotic muscle	9 (17)	34 (19.5)	43 (18.9)	
	Aggressive treatment with fluids and diuretics to prevent systemic complications [a]	11 (20.8)	21 (12.1)	32 (14.1)	
	Immediate hemodialysis	1 (1.9)	2 (1.1)	3 (1.3)	
	I don't know	29 (54.7)	106 (60.9)	135 (59.5)	
What is the appropriate action when a lightly injured casualty (for example, with limb wounds) presents to the hospital?	The patient should be directed to a designated site deployed outside the hospital area	12 (22.6)	47 (27)	59 (26)	0.925
	The patient should enter the hospital area and be provided with immediate treatment	22 (41.5)	65 (37.4)	87 (38.3)	
	The patient should be evacuated to a distant hospital for treatment [a]	2 (3.8)	10 (5.7)	12 (5.3)	
	The patient should be directed to a designated site to be treated by a social worker/psychologist	3 (5.7)	8 (4.6)	11 (4.8)	
	I don't know	14 (26.4)	44 (25.3)	58 (25.6)	

Table A1. *Cont.*

Question	Correct Answers as *n* (%)				*p*-Value (Chi-Square Test)
	Categories	**Female (*n* = 53)**	**Male (*n* = 174)**	**All (*n* = 227)**	
What is the appropriate action when a severely injured person (for example, suffering from crush syndrome or needing amputation) presents to the hospital?	The patient should be directed to one of the designated sites deployed outside the hospital area	7 (13.2)	25 (14.4)	32 (14.1)	0.532
	The patient should enter the hospital area and be provided with immediate treatment [a]	32 (60.4)	90 (51.7)	122 (53.7)	
	The patient should be evacuated to a distant hospital for treatment	2 (3.8)	11 (6.3)	13 (5.7)	
	The patient should be directed to a designated site to be treated by a social worker/psychologist	0 (0)	9 (5.2)	9 (4)	
	I don't know	12 (22.6)	38 (21.8)	50 (22)	
What is the appropriate action when an anxiety-stricken patient presents to the hospital?	The patient should be directed to one of the designated sites deployed outside the hospital area	6 (11.3)	25 (14.4)	31 (13.7)	0.687
	The patient should enter the hospital area and be provided with immediate treatment	2 (3.8)	15 (8.6)	17 (7.5)	
	The patient should be evacuated to a distant hospital for treatment	1 (1.9)	5 (2.9)	6 (2.6)	
	The patient should be directed to a designated site to be treated by a social worker/psychologist [a]	31 (58.5)	87 (50)	118 (52)	
	I don't know	13 (24.5)	42 (24.1)	55 (24.2)	

Table A1. *Cont.*

Question	Correct Answers as *n* (%)				*p*-Value (Chi-Square Test)
	Categories	Female (*n* = 53)	Male (*n* = 174)	All (*n* = 227)	
Following a flood, how will the control and communication inside the hospital be conducted?	No organized report mechanism can be implemented during an emergency	3 (5.7)	5 (2.9)	8 (3.5)	0.128
	There is need to report solely to the director of the emergency department	1 (1.9)	14 (8)	15 (6.6)	
	An emergency operation center will be created by the management [a]	12 (22.6)	41 (23.6)	53 (23.3)	
	An emergency operation center will be created by the management and turned to only when needed	12 (22.6)	66 (37.9)	78 (34.4)	
	I don't know	25 (47.2)	48 (27.6)	73 (32.2)	
Immediately following a flood, collapse of communication mechanisms may occur between the hospital and external institutions. Who should be reported to during this time?	The regional EMS (emergency medical services) center via ambulance drivers	25 (47.2)	90 (51.7)	115 (50.7)	0.339
	There is a need to wait for renewal of communication channels, and then a report should be submitted to the Ministry of Health	5 (9.4)	19 (10.9)	24 (10.6)	
	Media reporters (television, radio)	3 (5.7)	2 (1.1)	5 (2.2)	
	The police via local/field police teams [a]	3 (5.7)	14 (8)	17 (7.5)	
	I don't know	17 (32.1)	49 (28.2)	66 (29.1)	

Data are expressed as *n* (% of participants). [a] Correct answer according to published data.

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International Journal of
Environmental Research and Public Health

MDPI

Article

Alcohol and Road Accidents Involving Pedestrians as Unprotected Road Users

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Received: 19 October 2020; Accepted: 1 December 2020; Published: 2 December 2020

Abstract: According to the World Health Organization (WHO), more than half of all road fatalities involve vulnerable road users, i.e., pedestrians, cyclists, and motorcyclists. Poland is classified as one of the European Union (EU) countries marked by low road safety, with a higher frequency of accidents involving pedestrians compared to other EU countries (31% of all fatalities). Among unprotected road users, a significant group of victims are pedestrians, who are often under the influence of alcohol. This study aims to analyze the impact of alcohol on the risk of occurrence and consequences of road accidents among pedestrians. The source of data was the medical documentation of the Department of Forensic Medicine of the Medical University of Warsaw. In more than half of pedestrian deaths, the presence of alcohol was found; regardless of the place of the event and the place of death, among the victims under the influence of alcohol, males dominated; the average age of the victims under the influence of alcohol was significantly lower compared to the average age of sober victims, with younger victims being significantly more likely to die at the scene of the accident, especially in rural areas; significantly higher alcohol concentrations were found in males, in victims who died at the scene of the accident, and with victims of accidents in rural areas. Among pedestrian traffic accident fatalities, the most numerous group comprised young men under the influence of alcohol. In rural areas, a higher percentage of pedestrian victims died at the scene as a result of excessive alcohol consumption. These areas should be subject to intensive preventive measures to increase the safety of pedestrians as unprotected road users.

Keywords: alcohol; ethanol; pedestrians; traffic accidents

1. Introduction

Unprotected road users constitute 46% of the global percentage of road fatalities [1]. According to Polish Police statistics for the years 2009–2019, the lowest percentage of unprotected road traffic participants among all victims of road accidents was recorded in 2009, i.e., 37.0% [2]. In 2014, it was as much as 43.5%, while currently unprotected road users constitute 40.0% of all road accident victims [3–9]. This group, therefore, deserves special attention, because unlike road users using cars, they are not protected by the car body and cannot rely on airbags or seat belts. Statistics of road accidents in Poland show that a significant group of participants in road accidents are pedestrians. During the decade

(2009–2019), 104,036 accidents were recorded (26.5% of total road accidents), in which 11,842 pedestrians were killed (31.7% of the total), (Table 1).

Table 1. Road accidents involving pedestrians in Poland, 2009–2019.

Year	Road Accidents	Deaths	Accidents Involving Pedestrians	% of Total	Deaths	% of Total
2009	44,196	4572	12,834	29.0	1477	32.3
2010	38,832	3907	11,286	29.0	1245	31.9
2011	40,065	4189	11,220	27.9	1419	33.9
2012	37,046	3571	10,309	27.8	1167	32.7
2013	35,847	3357	9489	26.5	1147	34.2
2014	34,970	3202	9106	26.0	1127	35.2
2015	32,967	2938	8581	26.0	923	31.4
2016	33,664	3026	8461	25.1	868	38.7
2017	32,760	2831	8197	25.0	873	30.8
2018	31,674	2862	7548	23.8	803	28.1
2019	30,288	2909	7005	23.1	793	27.3

Source: Own elaboration based on statistics, road accidents—annual reports.

The main causes of accidents involving these pedestrians under the influence of alcohol are careless stepping onto the road in front of a moving vehicle, lying down, sitting, standing, or even sleeping on the road [2]. Most accidents and casualties among pedestrians are caused by vehicle drivers, especially drivers of passenger cars [10–12]. Such accidents are mostly "running over a pedestrian" [13]. Most pedestrian accidents occur in built-up areas, but the consequences of accidents occurring outside built-up areas are more tragic and often result in death at the scene of the accident. The reasons for this can be attributed, among other things, to poorly lit roads outside built-up areas, which make pedestrians less visible, especially during bad weather conditions [14,15]. Furthermore, excessive speeding of vehicles outside built-up areas, the later arrival of specialist assistance at the scene of the accident, and the state of intoxication of pedestrian road users also contribute to this [2].

This study aims to analyze the impact of alcohol on the risk of occurrence and the consequences of traffic accidents among pedestrians as unprotected road users.

2. Materials and Methods

2.1. Materials

We obtained data from the documentation of the Department of Forensic Medicine (DFM) of the Medical University of Warsaw. Retrospective analysis included 321 out of 370 pedestrian traffic accident victims from the Warsaw area, recorded in the DFM death records. The analysis took into account the gender and age of the victims, mechanism of injury, bodily injuries, place of death (at the scene, at the hospital), place of event, i.e., the area of the Warsaw metropolis (Warsaw city, urban area, and rural areas). Although customarily in research, the scene of the incident is divided into built-up and undeveloped areas, based on the available materials, it would be difficult to unequivocally assess whether we are dealing with a built-up area or not, because according to the Polish codex definition, the beginning and end of the road section running through a built-up area are marked with appropriate information signs, which is practically impossible to verify based on documentation alone. Therefore, the proposed tripartite division seems to be more precise. In official statistics, urban and rural areas are distinguished based on the territorial division of the country. Urban areas (cities) include areas located within the administrative boundaries of cities, i.e., areas of urban communes and cities in urban–rural communes. Rural areas (villages) include areas outside the administrative borders of cities, which include areas of rural communes and rural parts of urban–rural communes. Warsaw is the largest city in Poland in terms of population and area. The analysis also included ethyl alcohol concentration in blood, muscles, and vitreous humor, determined based on toxicological examination performed by gas chromatography, expressed as per mille (‰). The obtained data were analyzed by comparing two groups, i.e., pedestrian victims under the impact of ethyl alcohol at the time of the

accident (≥0.2‰), n = 166, and sober pedestrian victims (0.0‰), n = 155. We eliminated unexplained deaths from this analysis, as to the place of the event, place of death, and type of vehicle involved in the event, n = 49.

2.2. Methods

Statistical analyses were carried out using IBM SPSS Statistics version 24. A series of chi-square analyses, Pearson correlation analyses, a series of one-factor ANOVA variance analyses, Student's t-analyses, and logistic regression analysis were performed. The typical threshold of $p < 0.05$ was assumed as the level of significance; however, the results of the probability of test statistics at the level of $0.05 < p < 0.1$ were interpreted as significant at the statistical trend level.

3. Results

In the analyzed population, n = 214 were men (66.67%). The age of the examined victims was varied, ranging from three to ninety-one years, with the average age being 54 ± 20.34 years. Alcohol was found in 166 of the victims (51.71%). The largest part (n = 283) of the investigated pedestrians who were struck experienced injuries to numerous regions of the body (88.16%), death occurred at the crash site for 217 of the victims (67.60%), and n = 212 victims were injured in crashes due to passenger cars (66.04%). The results are presented in Table 2.

Table 2. Distribution of analyzed variables.

Variables	Alcohol Group n = 166 (51.71%)	No Alcohol Group n = 155 (48.29%)	p Value
Gender n (%)			
Women	27 (16.27)	80 (51.61)	$p < 0.001$
Men	139 (83.73)	75 (48.39)	
Age n (%)			
Mean	45.87 ± 14.20	62.72 ± 22.26	$p < 0.001$
Median	48	71	
Minimum	15	3	
Maximum	86	91	
Bodily injuries n%			
Numerous regions of the body *	146 (87.95)	137 (88.39)	$p > 0.05$
Other	20 (12.05)	18 (11.61)	
Location of accident n (%)			
Warsaw city	46 (27.71)	93 (60.00)	$p < 0.001$
Urban areas	34 (20.48)	23 (14.84)	
Rural areas	86 (51.81)	39 (25.16)	
Death place n (%)			
At the scene of the accident	136 (81.93)	81 (52.26)	$p < 0.001$
Within 1 day of hospitalization	30 (18.07)	74 (47.74)	
Mechanism of injury n (%)			
Passenger car	121 (72.89)	91 (58.71)	$p < 0.05$
Lorry/delivery truck/bus	21 (12.65)	32 (20.64)	
Tram	4 (2.41)	17 (10.97)	
Train	16 (9.64)	11 (7.10)	
Other vehicle	4 (2.41)	4 (2.58)	

* Multiple injuries.

Regardless of where the accident occurred, men dominated the group under the influence of alcohol. In the group of sober victims, a slight predominance of women was observed. The size of the effect was high for rural areas, slightly lower for Warsaw, and moderate for urban areas of the Warsaw area (Table 3).

Table 3. Number of victims by group, gender, and location of accident.

Location of Accident			Under the Influence of Alcohol	Sober	X^2	Significance	φ
Warsaw city	Women	Number	7	47	16.16	<0.001	0.34
		% of the group	15.22%	50.54%			
	Men	Number	39	46			
		% of the group	84.78%	49.46%			
Urban areas	Women	Number	8	12	4.94	0.026	0.29
		% of the group	23.53%	52.17%			
	Men	Number	26	11			
		% of the group	76.47%	47.83%			
Rural areas	Women	Number	12	21	21.98	<0.001	0.42
		% of the group	13.95%	53.85%			
	Men	Number	74	18			
		% of the group	86.05%	46.15%			

X^2—the result of the chi-square test.

Additionally, regardless of where the accident occurred, the average age of the victims under the influence of alcohol was significantly lower compared to the average age of sober victims. The strongest effect of this group was observed in Warsaw (accordingly: 45.96 ± 16.11 vs. 65.61 ± 20.41 years, t = −5.71 $p < 0.001$, $d = 1.03$).

Chi-squared analysis, taking into account the group and place of the accident, divided into two age categories, i.e., younger and older victims of accidents ($Me = 55$), showed that younger victims affected by alcohol dominated in rural areas of Warsaw, while older victims were sober in Warsaw. In both cases, the size of the effect was moderate (Table 4).

Table 4. Number of victims by group, location of accident, and age category.

			Under the Influence of Alcohol	Sober	X^2	Significance	Cramér's *V*
Younger	Warsaw city	Number	32	23	9.86	0.007	0.24
		% of the group	26.02%	51.11%			
	Urban areas	Number	22	7			
		% of the group	17.89%	15.56%			
	Rural areas	Number	69	15			
		% of the group	56.10%	33.33%			
Older	Warsaw city	Number	14	70	12.08	0.002	0.28
		% of the group	32.56%	63.64%			
	Urban areas	Number	12	16			
		% of the group	27.91%	14.55%			
	Rural areas	Number	17	24			
		% of the group	39.53%	21.82%			

X^2—the result of the chi-square test.

When considering group and gender by location of death, it was found that in the group under the influence of alcohol, the majority were men, both when the death occurred at the scene of the accident and within the first day of hospitalization. In the group of sober victims, a slight predominance

of women was observed, especially when death occurred at the scene of the accident. When death occurred within the first day of hospitalization, the groups were the same. The size of the effect was quite high in both cases (Table 5).

Table 5. Number of victims by group, gender, and location of death.

			Under the Influence of Alcohol	Sober	X^2	Significance	φ
At the scene of the accident	Women	Number	23	43	31.39	<0.001	0.38
		% of the group	16.91%	53.09%			
	Men	Number	113	38			
		% of the group	83.09%	46.91%			
Death within 1 day of hospitalization	Women	Number	4	37	12.02	0.001	0.34
		% of the group	13.33%	50.00%			
	Men	Number	26	37			
		% of the group	86.67%	50.00%			

X^2—the result of the chi-square test.

Irrespective of the location of death, the average age of victims under the influence of alcohol was significantly lower compared to the average age of sober victims. The size of the effect of the group for both variants was equally high (Table 6).

Table 6. Average age of victims by group and location of death.

	Under the Influence of Alcohol		Sober				95% CI		
	M	SD	M	SD	*t*	*p*	LL	UL	Cohen's *d*
At the scene of the accident	45.16	14.10	59.93	21.89	−5.44	<0.001	−20.14	−9.39	0.85
Death within 1 day of hospitalization	49.07	14.47	65.78	22.41	−4.51	<0.001	−24.10	−9.33	0.82

M—average (for age), SD—standard deviation, *t*—Student's *t*-test result, *p*—significance level, 95% CI—confidence interval, LL, UL—is the lower and upper limits of the confidence interval.

The analysis taking into account the group and location of death, split into two age categories, showed that younger victims under the influence of alcohol died more often at the scene of the accident, while sober older victims died on the first day of hospitalization. The size of the effect was moderate but slightly weaker than that in the group of younger victims, $Vc = 0.23$ (Table 7).

Table 7. Number of victims by group, location of death, and age category.

			Under the Influence of Alcohol	Sober	X^2	Significance	Cramér's *V*
Younger	At the scene of the accident	Number	105	29	8.93	0.003	0.23
		% of the group	85.37%	64.44%			
	Death within 1 day of hospitalization	Number	18	16			
		% of the group	14.63%	35.56%			
Older	At the scene of the accident	Number	31	52	7.67	0.006	0.22
		% of the group	72.09%	47.27%			
	Death within 1 day of hospitalization	Number	12	58			
		% of the group	27.91%	52.73%			

X^2—the result of the chi-square test.

Frequency analysis was also performed by location of accident, location of death, and group. Differences were found at the border of the statistical trend in the victims under the influence of alcohol,

in which the highest number was recorded in rural areas of Warsaw, especially those who died at the scene of the accident, $p = 0.058$. The size of the effect was moderate, $Vc = 0.19$ (Table 8).

Table 8. Number of victims by location of accident, location of death, and group.

			Warsaw city	Urban Areas	Rural Areas	X^2	Significance	Cramér's *V*
Under the influence of alcohol	At the scene of the accident	Number	33	27	76	5.78	0.058	0.19
		% of location of accident	71.74%	79.41%	88.37%			
	Death within 1 day of hospitalization	Number	13	7	10			
		% of location of accident	28.26%	20.59%	11.63%			
Sober	At the scene of the accident	Number	43	13	25	3.71	0.152	0.16
		% of location of accident	46.24%	56.52%	64.10%			
	Death within 1 day of hospitalization	Number	50	10	14			
		% of location of accident	53.76%	43.48%	35.90%			

X^2—the result of the chi-square test.

The presence of ethyl alcohol was noticed in more than 51% of fatal pedestrian victims. Its concentration was 2.05 ± 0.895 per mille and it was in the range of 0.2–4.4‰, with ethanol concentration in men being statistically higher (2.12 ± 0.87) compared to the women's concentration (1.69 ± 0.95, $p = 0.021$, $d = 0.49$).

An analysis of Pearson's *r* correlation between alcohol level and age was performed. The relationship proved to be statistically insignificant, which means that there was no correlation between age and alcohol level, $r = 0.05$, $p = 0.487$.

Analogous correlation analysis was performed with additional consideration of the gender of the victims. The analysis did not show statistically significant differences, which means that no correlation was observed between age and alcohol level in either women or men (respectively: $r = 0.03$, $p = 0.686$ vs. $r = 0.15$, $p = 0.463$).

Analysis of the alcohol level by type of injury showed differences at the border of the statistical trend. The alcohol level was found to be lower in victims who suffered injuries to numerous regions of the body, compared to those who suffered other bodily injuries (respectively, 2.01 ± 0.89 vs. 2.38 ± 0.91 per mille, $F = 3.02$, $p = 0.084$).

One-way analysis of variance, taking into account alcohol levels and the location of the accident, showed the highest concentration of alcohol in accident victims in rural areas of the Warsaw area (2.22 ± 0.81 per mille, $F = 5.36$, $p = 0.006$).

Analysis of the alcohol concentration by location of death showed differences at the borderline of the statistical trend, which means that victims who died at the scene of the accident had a higher alcohol concentration than those who died on the first day of hospitalization (respectively 2.11 ± 0.90 vs. 1.77 ± 0.83 per mille, $F = 3.56$, $p = 0.061$).

One-way analysis of the variance including alcohol concentration and the injury mechanism showed no statistically significant differences, which means that the alcohol concentration of pedestrian victims did not differ according to the type of vehicle involved in the event, $F = 0.31$, $p = 0.87$.

A logistic regression analysis was also conducted to examine the simultaneous impact of all measured predictors on the probability of death in a road accident among alcohol-drunk pedestrians. The applied regression model (Nagelkerke R^2) proved to be well suited to the data X^2 (9) = 129.73; $p < 0.001$. The fit of the model was also confirmed by the insignificant result of the Hosmer and Lemeshow test X^2 (8) = 6.83; $p = 0.555$. The constructed model explains 44.3% of the variance, obtaining the classification correctness at the level of 76.9%. Most of the predictors turned out to be statistically significant. The analysis showed that the chance of death in a road accident among pedestrians under the influence of alcohol was more than five times higher in men compared to that in women and

decreased with age by about 4% with each year of life. Moreover, the obtained results showed that pedestrians under the influence of alcohol were more likely to die in incidents involving passenger cars. The type of sustained injuries turned out to be insignificant, but the place of the accident and the place of death turned out to be significant variables. Thus, the chance of death in a road accident among pedestrians under the influence of alcohol was about twice as high in urban and rural areas of the Warsaw agglomeration compared to that in Warsaw Capital City, and the chance of death on the first day of hospitalization compared to that of death at the scene of the accident was approximately three times smaller (Table 9).

Table 9. Results of the logistic regression analysis testing the predictors of death in a road accident among pedestrians under the influence of alcohol.

	B	SE	X^2	p	OR	OR 95% CI	
						LL	UL
Gender *	1.63	0.32	26.48	<0.001	5.08	2.73	9.43
Age	−0.04	0.01	20.43	<0.001	0.97	0.95	0.98
Passenger car			8.71	0.069			
Lorry/delivery truck/bus	−0.80	0.38	4.44	0.035	0.45	0.21	0.95
Tram	−1.27	0.71	3.22	0.073	0.28	0.07	1.13
Train	−0.94	0.51	3.46	0.063	0.39	0.14	1.05
Other vehicle	−0.55	0.86	0.41	0.520	0.58	0.11	3.09
Bodily injuries **	0.01	0.45	0.00	0.980	1.01	0.42	2.44
Warsaw city			9.46	0.009			
Urban areas	0.87	0.40	4.68	0.031	2.39	1.09	5.24
Rural areas	0.94	0.33	8.35	0.004	2.57	1.36	4.87
Death place ***	−1.19	0.32	13.98	<0.001	0.30	0.16	0.57

* Men compared to women, ** other types of injuries compared to injuries to numerous regions of the body, *** death within 1 day of hospitalization compared to death at the scene of the accident. B—regression coefficient, SE—standard error, X^2—the result of the chi-square test, OR—odds ratio, OR 95% CI—confidence interval, LL, UL—lower and upper limits of the confidence interval.

4. Discussion

Although the risk of injury and death impacts all road users, there are significant differences in mortality rates between groups of victims. Pedestrians are a high-risk group [1,5].

According to annual reports from the Polish Police for the years 2011–2019, the greatest number of accidents in which pedestrians died were caused by drivers of passenger cars (for the years 2009 and 2010, there were no such data). The highest number of such events was recorded in 2011 (5486 accidents, from which 423 were killed) and the lowest in 2019 (3769, from which 257 were killed) [9]. Similarly, in the presented study, the majority of accidents in which pedestrians were killed were caused by passenger car drivers (Tables 2 and 9). In the group of sober victims, this was also the leading mechanism of injury, although there were also nearly twice as many victims of accidents involving lorries, vans, and buses, and about five times as many victims of tram accidents. Taking into account the fact that nearly 75% of sober victims died in the urban areas of the Warsaw area, with as much as 60.00% of them in Warsaw, it seems that the mechanism of injury is determined by the location of the accident.

According to WHO data, 75% of all people who die in road accidents worldwide are male [16]. In the presented analysis, men constituted nearly 67% of the studied population. It is believed that such a gender distribution among victims is probably caused by an increased tendency to take risky actions in the male group, especially under the influence of alcohol [5]. In the presented analysis, the gender imbalance was particularly significant in the group of pedestrians under the influence of alcohol, where there were more than five times more men than women. According to the Central Statistical Office (GUS), in 2014, the actual mortality rate per 100,000 population due to road accidents in Poland was 8.4 [17]. However, the risk of life for men is many times higher than that for women (standardized coefficient of road accident mortality for men is 12.4 vs. 3.3 for women). The phenomenon of high mortality due to road accidents in rural areas, for which the standardized death rates due to road

accidents were 16.9 for men and 4.2 for women, is also characteristic. In 2016, these rates were 17.8 for men and 4.6 for women [3,4]. The results obtained in this study are in line with this trend.

It is customary for studies presented in the literature to separate the location of the accident into built-up and non-built-up areas [18–20]. This is undoubtedly important in the context of the speed reached by vehicles, which has an impact on the consequences of traffic accidents. "At high vehicle speeds, pedestrians and cyclists suffer the most severe consequences of accidents. It is in these cases when the kinetic energy released during an impact must be counteracted by the resilience of the human body. The results of the study indicate that when a vehicle impacts at 30 km/h, 9 out of 10 pedestrians will survive the accident; at 50 km/h, half of them will die; and at a speed exceeding 60 km/h, 9 out of 10 will die. These values are higher for older pedestrians (>60 years)" [21].

It is worth mentioning at this point that in Poland the speed limits are set following the rule of law, and appropriately to whether or not it is a built-up area. However, according to the law, there may be local restrictions other than the standard ones for built-up areas (e.g., changing the speed limit in a built-up area from 50 km/h to a maximum of 70 km/h in places where there are pedestrian crossings) [21]. Furthermore, the actual speed of the vehicle involved in an accident is normally the subject of an investigation into the circumstances of the accident, the findings of which remain classified. Thus, as the speed of the vehicle increases, the kinetic energy released during a collision also exponentially increases, increasing the risk of death and serious injury. Regarding the available materials, it would be difficult to assess whether or not we are dealing with a built-up area, because according to the Polish definition of the code, the beginning and the end of a section of road passing through a built-up area are marked by appropriate road signs, which is practically impossible to verify based on documentation alone [22]. This study also did not examine the cause–effect relationships, so the three divisions into the Capital City of Warsaw and rural and urban areas of the Warsaw area seemed to be more precise. It is also a source of new, valuable information in the context of the epidemiology of traffic accidents involving pedestrians.

The consequences of this study established that victims were mainly younger men (Me = 55) under the influence of alcohol, and the highest rates of these types of incidents were observed in rural areas. These victims were most often killed at the scene of the accident. According to the study of de Carvalho Ponce et al. on the impact of alcohol in traffic crashes in Sao Paulo, the victims of road crashes were mostly men aged 25–34 years. Similar consequences have been mentioned by Gjerde et al., who analyzed the effect of alcohol and psychoactive substances on road crashes in Norway, as well as Hickox et al., who analyzed pedestrian mortality in Clark County, Nevada. De Boni et al., in their research on factors related to alcohol consumption and drugs by participants of road crashes in southern Brazil, demonstrated that the victims were also mainly men, with the average age being 37 years [23–26].

Studies on the role of the impact of alcohol in road accidents indicate that ethyl alcohol is a factor that significantly impacts their occurrence and consequences. This study showed that pedestrians under the influence of alcohol are significantly more likely to die at the scene of the accident, and the frequency of this rises with the increase in alcohol concentration. The increase was especially significant in the rural parts of the Warsaw area, where the substantial majority of the pedestrians also died at the scene of the road crash. However, this does not necessarily have to be the result of injuries, although indeed almost all pedestrians were found to have received injuries in numerous regions of the body, i.e., multiple injuries representing injuries to at least two or more regions of the body, each of which is an indication for hospital treatment.

It seems that the location of the accident itself may be of significance here. The most numerous group of pedestrian deaths was recorded in Warsaw city (43.30%). This result is not surprising, considering the specificity of Warsaw as a place with an exceptionally high concentration of traffic. According to reports on the State of Road Traffic Safety in the Capital City of Warsaw for the years 2009–2019, the most common type of accidents on the capital's streets were those involving pedestrians. The highest number of such events, i.e., 492 (45.8% of the total) and 38 killed (66.6% of the total),

occurred in 2010, while the lowest number occurred in 2019, i.e., 302 (33.4% of the total) and 21 killed (60.0% of the total). Although their number is decreasing, the pedestrian is still the most vulnerable road user on the capital's streets [23–25]. The percentage of pedestrian deaths in rural areas was slightly lower (38.94%), but the percentage of victims under the influence of alcohol was the highest (51.81%). Sober pedestrians accounted for only 25.16%. The lowest percentage of pedestrian victims was in urban areas of the Warsaw area (17.76%), where sober pedestrians constituted 14.84%, while in the Capital City of Warsaw it was as much as 60%.

In contrast to pedestrians under the influence of ethyl alcohol, who constitute nearly 82% of cases who died at the scene of the accident, sober pedestrians died on the first day of hospitalization in over 47% of cases. Similar conclusions are presented in the Road Safety Report in Poland, according to which the most numerous and most severely impacted group of victims compared to other road users are pedestrians, who statistically more often die at the scene of the accident or during hospitalization and represent a higher percentage of the severely injured [27,28].

According to legal standards in Poland, when the blood alcohol content is or nears a concentration of 0.2‰ to 0.5‰ (or the presence of 0.1 mg to 0.25 mg of alcohol in 1 dm^3 in exhaled air), this is considered a state after alcohol consumption [22]. When the blood alcohol level is or nears a blood alcohol level above 0.5‰ (and there is more than 0.25 mg in 1 dm^3 in the exhaled air), we are talking about a state of intoxication [29–32]. Unfortunately, in the presented analysis, the above-mentioned limits were significantly exceeded in pedestrians (0.2–4.40‰). A comparison of ethyl alcohol concentration in pedestrian victims showed that alcohol consumption in pedestrian victims was significantly higher in men than in women. The highest alcohol concentrations were recorded in the victims who died at the scene of the accident, especially in rural areas of the Warsaw area.

5. Limitations

The presented analysis has some limitations, as it only takes into account the fatalities of pedestrian traffic accidents. This study also did not examine the cause–effect relationships, and it also does not take into account factors other than the presented risks affecting pedestrian safety, such as, for example, poorly lit roads, traffic intensity, season of the year, bad weather conditions, or the speed at which vehicles are moving. Furthermore, the Department of Forensic Medicine, from which we drew our data, is the major referral center in Warsaw and the only unit of this type at the Medical University of Warsaw. According to the importance of the problem, it is necessary to conduct further in-depth research in this area.

6. Conclusions

Alcohol is an important risk factor for road accidents involving pedestrians as unprotected road users. The most numerous group of road accident fatalities among pedestrians are men, with a particular emphasis on men under the influence of alcohol. In particular, victims under the influence of alcohol were more likely to die in crashes, when the place of the accident was in a rural area [33]. In these circumstances, death at the scene of an accident is equally common. Alcohol is of course one of the many factors that impact their safety; undoubtedly other factors include badly lit roads (outside built-up areas, roads are not illuminated, so pedestrians are less visible), the level of traffic intensity, the time of year (especially in autumn and winter, when visibility is worse in the earlier twilight), bad weather conditions, or the aforementioned speed at which vehicles are moving [34]. Death at the scene of the crash might be caused, among other things, by the inferior quality of pre-hospital care. Delays in detecting and providing care for those involved in a road traffic crash increase the severity of injuries. Intensive prevention programs ought to be implemented in these areas so that the safety of pedestrians can be improved [20,35–39]. This requires involvement from multiple sectors, such as police, health, education, transport, and actions that address the safety of roads, vehicles, and road users [40].

Author Contributions: Conceptualization, D.L.; validation, D.L.; formal analysis, D.L.; resources, P.K.; writing—original draft preparation, D.L., A.A.-W., K.G., and W.P.; writing—review and editing, D.L., A.A.-W., K.G., and W.P.; supervision, W.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

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International Journal of
Environmental Research and Public Health

MDPI

Commentary

Public Health Regulations and Policies Dealing with Preparedness and Emergency Management: The Experience of the COVID-19 Pandemic in Italy

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Citation: Aristei, L.; D'Ambrosio, F.; Villani, L.; Rossi, M.F.; Daniele, A.; Amantea, C.; Damiani, G.; Laurenti, P.; Ricciardi, W.; Gualano, M.R.; et al. Public Health Regulations and Policies Dealing with Preparedness and Emergency Management: The Experience of the COVID-19 Pandemic in Italy. *Int. J. Environ. Res. Public Health* **2022**, *19*, 1091. https://doi.org/10.3390/ijerph19031091

Academic Editor: Mariusz Goniewicz

Received: 30 December 2021
Accepted: 17 January 2022
Published: 19 January 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Abstract: Worldwide, the management of health emergencies requires a high degree of preparedness and resilience on the part of governments and health systems. Indeed, disasters are becoming increasingly common, with significant health, social, and economic impacts. Living in a globalized world also means that emergencies that occur in one country often have an international, in some cases global, spread: the COVID-19 pandemic is a cogent example. The key elements in emergency management are central governance, coordination, investment of resources before the emergency occurs, and preparedness to deal with it at all levels. However, several factors might condition the response to the emergency, highlighting, as for Italy, strengths and weaknesses. In this context, policies and regulation of actions to be implemented at international and national level must be up-to-date, clear, transparent and, above all, feasible and implementable. Likewise, the allocation of resources to develop adequate preparedness plans is critical. Due to COVID-19 pandemic, the European Commission proposed the temporary recovery instrument NextGenerationEU, as well as a targeted reinforcement of the European Union's long-term budget for the period 2021–2027. The pandemic highlighted that it is necessary to interrupt the continuous defunding of the health sector, allocating funds especially in prevention, training and information activities: indeed, a greater and more aware public attention on health risks and on the impacts of emergencies can help to promote virtuous changes, sharing contents and information that act as a guide for the population.

Keywords: health emergency; management; disaster legislation; preparedness; COVID-19

1. Introduction

The management of disasters and emergencies is a core function of Public Health. Indeed, natural or humanmade extraordinary events might constitute a public health risk that require a timely, coordinated, and efficient response from governments and healthcare systems. Disasters can be natural (geophysical, meteorological, hydrological, climatological, biological, extraterrestrial) or technological (humanmade—intentional or

nonintentional) [1], and they are defined as any occurrence that causes damage, ecological disruption, and loss of human life, resulting in a serious failure of the functioning of the community [2]. Moreover, the impact of these situations often exceeds the response capabilities of the community, requiring external assistance (at the national or international level) in terms of human, economic, structural and instrumental resources [3,4]. In recent years, the number of disasters and public health emergencies increased in frequency and intensity, causing a massive social disruption and thus requiring specialized management [5,6]. In particular, it is estimated that between 2005 and 2015, over 700,000 people died as a result of these phenomena, more than 1.4 million have been injured and 23 million have lost their homes, while economic losses exceeded 1.3 trillion USD. In addition, natural disasters between 2008 and 2012 caused the migration of about 144 million people [6]. Moreover, only in 2019, natural disasters involved about 95 million people with 11,775 deaths and 103 billion USD in economic losses worldwide [3].

Of note, an important issue for Public Health at the international level is represented by microbiological emergencies, which are becoming increasingly frequent. Indeed, the World Health Organization (WHO) monitored worldwide 1483 epidemics in 172 Countries between 2011 and 2018 [7] and, of these, epidemic-prone diseases such as influenza, severe acute respiratory syndrome (SARS), Middle East respiratory syndrome (MERS), Ebola, Zika, and SARS-CoV-2 represent a serious risk for the onset of epidemics or pandemics, as they are characterized by a potentially fast-spreading outbreaks worldwide [7]. Therefore, disasters have a huge health, social, and economic burden, with direct and indirect long-term consequences on the population, such as psychological and behavioral effects (increase of depression, anxiety, insomnia, stress) [5,8,9], economic losses [10,11] and social repercussions (increase of poverty, migrations of entire populations) [10,12,13]. In this context, adequate emergency preparedness and resilience of governments and healthcare systems, developed through a coordinated and integrated response guided by strong leadership and based on international policies, can lead to significant savings in lives and in economic resources [14]. Preparedness, in fact, is the ability to effectively anticipate, respond to, and recover from public health emergencies through vision, knowledge, skills of planning and organization of governments, communities, and individuals, at local, regional, national, and international level [15]. In particular, seven main skills (planning, coordination, timely diagnosis, evaluation, investigation, response, and communication) are required to guide strategies and mechanisms to face public health emergencies. Thus, these skills should be applied to four priority areas of action that can be implemented at both the national (and local) and supranational (and global) levels: understanding risk, enhancing governance, investing in risk reduction for resilience, and improving disaster preparedness in recovery and reconstruction [6]. Developing adequate preparedness plans, therefore, is a global priority, through transparent and coordinated policies shared by all countries.

In this commentary, we present an overview of the policies, regulatory frameworks and legislation on health emergency management at global and European level. Then we focus on the Italian COVID-19 pandemic as an example of management of health emergencies. Finally, this paper concludes by proposing some directives about the management of future emergencies.

2. Legislation and Policies on Health Emergency Management

2.1. Global and European Level

The attempt to manage and coordinate the response to health emergencies at international level began in 19th century. The first International Health Conference, in fact, was organized in 1851 after the European cholera epidemy (1830–1847) [16]. Then, the first two international conventions on health emergencies were approved in 1892 and in 1897 on cholera and plague control, respectively [17]. In 1946, the WHO was created and in 1969 the International Health Regulations (IHRs), an instrument of international law, were approved to share epidemiological information to prevent, respond and control the spread of infectious diseases across borders, without interfering with international trade

and movement [18]. In May 2005, due to globalization, IHRs were adjourned, becoming legally binding. In this context, IHRs defined the notification criteria to WHO for infectious diseases of urgent importance for international public health, such as those with rapid transmission, high lethality, newly identified syndrome, and possible restrictions on trade or travel. Moreover, Member States had the duty to develop, strengthen and maintain the capacity to respond promptly and effectively to public health risks and health emergencies of international concern [19].

In Europe, the first emergency regulation was approved in 1998 and Council Decision n. 2001/792 established the European Civil Protection, (reformed in 2013) to strengthen and coordinate disaster prevention, preparedness, and response [20,21]. Then, two action plans were adopted in 2005 (n. 605 and 607) to help states draw up and adopt health management plans [22,23]. Additionally, national, European (European Centre for Disease Prevention and Control—ECDC) and global (WHO) management and control centers of public health emergency were linked with each other to promptly notify and activate alert situations. In March 2004, the European Commission adopted a preparedness plan COM(2004)201 that sets out actions in management and coordination, surveillance, prevention, mitigation and response, communication, civil protection and research's areas [24]. It was then amended by Communication COM(2005)607 [23], which identified six phases of an influenza pandemic as defined by the WHO (no virus subtype circulating; circulation of a virus subtype between animals with risk to humans; human infection with no interhuman transmission; limited interhuman transmission; increased but localized interhuman transmission; increasing and sustained transmission among the population) [25]. In each phase, responsibilities are shared between the European Commission, Member States and the ECDC (established in 2004). Decision n. 1082/2013 repealed 1998 decision, establishing that Member States and the Commission consult each other within the Health Security Committee (HSC), through the creation of the Early Warning and Response System (EWRS) to notify serious cross-border threats to health [21]. Once a risk alert has been notified, the Commission provides the National Authorities and the HSC a risk assessment of the threat's potential severity to public health, coordinating actions.

During the COVID-19 pandemic, the European Commission adopted Communication COM(2020)724 to strengthen European Union (EU)'s resilience and coordination to cross-border health threats [26]. This Communication aims to strengthen the ECDC's mandate and expand that of the European Medical Agency (EMA). Additionally, this Communication strengthens emergency management tools (such as countermeasures or medical devices) when national capacities are insufficient, complementing EU Civil Protection capabilities. On 16 September 2021, the European Commission inaugurated the Health Emergency preparedness and Response Authority (HERA) to prevent, detect, and respond rapidly to health emergencies. In particular, if a public health emergency is declared at EU level, HERA can move quickly to emergency operations activating emergency funding and initiating monitoring mechanisms.

2.2. Financial Interventions as COVID-19 Emergency Response in Europe

On 2 May 2018, the European Commission presented its proposal for the next long-term EU budget and on 27 May 2020, due to COVID-19, it proposed the temporary recovery instrument NextGenerationEU (NGEU) [27], as well as a targeted reinforcement of the EU's long-term budget for the period 2021–2027. On December 2020, the EU Council adopted the long-term budget 2021–2027 [28] and the European Parliament and the Council reached an agreement on the Recovery and Resilience Facility (with EUR 723.8 billion in loans and grants), the key instrument underpinning NGEU [29]. NGEU is a temporary recovery facility (more than EUR 800 billion) that will help repair the immediate economic and social damage caused by COVID-19 to create a greener, more digital, and resilient Europe. It will also allocate additional funding to other European programs or funds, such as Horizon Europe or InvestEU. Moreover, there are other plans such as REACT-EU that allocates EUR 50.6 billion for the expansion of crisis response measures and EU4Health, to address

the resilience of health systems (EUR 5.3 billion) [30]. Established by Regulation (EU) 2021/522, EU4Health will improve and promote health in the EU, addressing cross-border health threats. HERA's activities will also have a budget of EUR 6 billion from the current Multiannual Financial Framework for the period 2022–2027.

2.3. Italian Legislation on Health Emergency Management

The Italian Constitution does not contain specific rules on the state of emergency. However, based on article 77, the Government can adopt decrees in the cases of extraordinary necessity and urgency, concerning the concrete management of emergencies; also, article 120 allows the Government to replace local authorities in events of danger to public safety and security. Moreover, Article 117(3) states that the state must establish health principles.

Law 8 December 1970, No. 996, was the first identifying ordinary (Interior Minister, Prefect, Regional Government Commissioner, Mayor) and extraordinary (Extraordinary Commissioner) Civil Protection's bodies as well as their competences [31]. In the Civil Protection's system, state bodies (Prefect and Government Commissioner) mainly managed the emergency. Law 24 February 1992, No. 225, established the National Service of Civil Protection that deals with relief, forecasting, and prevention, defining natural disasters' causes and the risks for the territory. It also takes all the appropriate and necessary actions to reduce or avoid damages from natural disasters. The 1992 law reorganized Civil Protection's structure as a coordinated system of competences in which public and private entities participate. Law 24 February 1992 was repealed by legislative decree 2 January 2018, No. 1 (Civil Protection Code) [32]. This code reiterates a polycentric model, in which all local and voluntary bodies are involved, providing a coordinated emergency management system (relief and assistance interventions, allocation of funds).

Indeed, in case of emergency, a bottom-up pyramidal response mechanism is activated, starting from the level closest to citizens. Therefore, the mayor (law 18 August 2000, n. 267) directs and coordinates relief operations, assisting the population and organizing municipal resources [33]. He/she can also approve contingent and urgent orders to prevent and eliminate serious dangers threatening public safety and urban security. The mayor has then to draw up the Municipal Emergency Plan (MEP) and if he/she is unable to cope with the event by its own means, the higher local levels are involved (Province, Prefecture, Region, Ministry of Health—State). Moreover, at local level, in the case of infectious emergency, the Prevention Department (a technical-functional structure of the Local Health Authorities) are responsible for the management of infectious cases and outbreaks.

Nationally, the Council of Ministers' President coordinates measures with Civil Protection Department, appoints delegated Commissioners and specific task forces, and issues emergency ordinances to avoid dangerous or damaging situations. The Council of Ministers, based on President's proposal, decrees the state of emergency indicating its territorial extension and duration (it cannot exceed 12 months, and can be extended for no more than a further 12 months) [32].

Finally, Agencies in support of the Ministry of Health carry out technical-scientific consulting activities (National Health Institute—ISS), drug regulatory activities (Italian Medicines Agency—AIFA), and health performance monitoring and control (National Agency for Regional Health Systems—AGENAS).

2.4. Financial Interventions as COVID-19 Emergency Response in Italy

The Italian Recovery and Resilience Plan was approved on 22 June 2021 by the European Commission [34]. It responds to the urgent need to foster a strong recovery, making Italy more sustainable, resilient, and better prepared. The Plan will be supported by EUR 68.9 billion in grants and EUR 122.6 billion in loans, and all reforms and investments must be implemented by August 2026. Mission 6 directs resources to resilience's strengthening and timeliness of the National Health System's response to emerging infectious diseases with high morbidity and mortality, as well as to other health emergencies. Additionally, it tends to develop proximity healthcare and stronger integrations between health, social,

and environmental policies to foster effective social inclusion. It also aims to invest in medical assistance's digitalization, promoting the spread of the Electronic Health Record and telemedicine, adopting digital technologies in the field of medical assistance and prevention services. Regarding territorial and proximity medicine, the investments of the Plan are oriented toward strengthening the instruments for care in the territory and in the homes of patients (e.g., using telemedicine), especially those with chronic diseases, to leave hospital care only when necessary. An example is represented by the creation of "Case della Comunità–Community Homes", which are health care facilities that promote a multidisciplinary intervention model for planning social interventions and social-health integration.

To fight the pandemic, Italy also approved several decree laws for urgent measures that have provided for a significant increase finance in the standard national health requirement (+EUR 1410 million for 2020 established by the so-called Cura Italia decree) [35]. Cura Italia also recognized to Regions, for the whole state of health emergency period, to issue special insurance coverage for the purchase of goods related to the management of the epidemiological crisis. Then, Liquidity Decree provided a tax credit for companies to sanitize workplaces, purchase surgical masks and personal protective equipment, extended by Cura Italia also to non-commercial entities [36]. In addition, through the Fund for national emergencies (refinanced by the Rilancio Decree) [37] Cura Italia financed the purchase of facilities and equipment specifically for the treatment of COVID-19 patients, finances used mainly by the Civil Protection Department and the Extraordinary Commissioner for the emergency.

3. The Management of the COVID-19 Pandemic in Italy: Strengths and Weaknesses

Italy was the first western country affected by the COVID-19, representing the frontline against the pandemic, with a mortality rate among the highest in Europe, especially during the first wave [38]. In this context, in order to quickly respond and manage the emergency, the government declared the state of emergency on 31 January 2021 [39]. Therefore, several immediate actions have been implemented to contain the spread of the virus, also in accordance with the eight pillars proposed by WHO [40]. Among these, the creation of specific task forces of experts and the involvement of technical and scientific support bodies at national (ISS, AIFA) and regional level to provide scientific advice to the government, and the allocation of significant economic resources (EUR 3.7 billion in 2020 and EUR 1.7 billion in 2021) to health systems [41] in order to enhance epidemiological surveillance, testing capacity and laboratory activities, to increase hospital facilities and intensive care units beds, and to create of special units to manage COVID-19 patients, establishing a COVID-19 integrated surveillance system [41–43].

However, several factors have made it difficult to implement a rapid and coordinated response. In particular, Italy has 20 different regional health care systems [44], and decentralization may have hindered preparedness [45]. In fact, the weak coordination with regional bodies, has led, especially in the early phase of the pandemic, to a frail and uneven response, with some regions implementing autonomous policies (testing, contact tracing, containment measures) not always in line with the central government [43,44,46]. In addition, in some cases the lack of coordination between hospital and primary care and territorial services has resulted in an inefficient response, with saturation of hospitals and inability to manage patients [44,47]. Similarly, due to lack of previous economic efforts on digital innovation, the absence of a strong and implemented digital health structure has reduced the possibilities of telemedicine and home management of mild symptomatic cases [48].

Furthermore, Italy show several limits in capacity planning of the hospitals. In particular, the enormous pressure generated on the healthcare system during the first and the subsequent waves caused by variants (such as omicron) highlighted the need to develop models for hospital surge capacity planning [49–51]. Indeed, given the emergence of new waves, it is a priority to identify risk scenarios that consider many factors, before reaching the crisis point: the current status of the disease, how quickly it spreads (e.g., doubling

time), the degree of containment measures being deployed, the availability of healthcare workers, the hospital capacity in terms of beds and ventilator requirements [52]. In this context, at the end of the first wave the task force of experts in collaboration with the main Italian technical-scientific bodies developed four risk scenarios still in use through the creation of specific indicators of probability (virus transmission capacity, time of doubling of cases, spread in working and school environments), impact on hospitals (occupancy of beds in ordinary wards or intensive care units) and resilience (degree of acceptance of hygiene, health and behavioral measures by the population, contact tracing capacity, ability to carry out early diagnosis and monitoring of positive cases) [53]. In this way, regions are classified in four areas—white, yellow, orange, and red—that correspond to as many risk scenarios and for which specific restrictive measures are foreseen [54]. The implementation of these systems has led to the conversion of hospitals into specific COVID-19 structures, highlighting a good degree of resilience of healthcare facilities. The identification of these parameters and risk scenarios allows the creation of models that can facilitate the reconfiguration for disaster-resilient health infrastructure, also applicable to other types of health emergencies (i.e., earthquakes, floods, other infectious outbreaks) [55,56].

Finally, the constant defunding of the National Health Service in Italy in recent decades, which has led to a shortage of healthcare workers, insufficient structures and technology and the absence of integrated management, explains, at least partly, the difficulties in the management of the first wave of the pandemic [41,44].

4. Conclusions

The COVID-19 pandemic must represent a moment of awareness and reflection in order to improve governance processes and the ability to respond and react to disaster events. The COVID-19 emergency has confirmed that it is necessary to work more on the analysis of local contexts in order to design targeted interventions at regional and national level, improving the interaction and coordination between different settings. Planning and, therefore proper organization, represent the key to adapt and direct decision-making processes. The pandemic has highlighted how the current governance, often still anchored to laws, regulations and bureaucratic systems or apparatuses belonging to historical periods and contexts completely different from the current or future ones, is only partially able to provide a timely and coordinated response. Moreover, system resilience is a key issue in managing healthcare emergencies. In fact, the adaptive capacity of hospitals and in general of all healthcare facilities is essential to ensure rapid adaptation to an emergency. The pandemic has led to the development of predictive models and methodologies for risk assessment and quantification on which response measures to the spread and containment of the virus are developed. These models should be implemented and made feasible, not only in organizational and managerial terms but also in relation to structural, environmental, plant, engineering and technological aspects that can also be adapted to the context of other health emergencies, to ensure the presence of a resilient system capable of providing a quick, specific and personalized response as much as possible, with a major impact in terms of lives saved and reduction of social and economic damage. To make these models feasible, however, coordination and collaboration between the structures are necessary, both at a territorial and regional level, and mainly, at a national and central level, to overcome the regulatory conflicts, technical and legislative regulations that still exist and are not sufficiently corrected and updated on the basis of the current pandemic experience (Table 1).

In this context, the new European agency HERA represents an important step forward, although it is limited to the European Union and it still insufficient to ensure a timely, transparent, and coordinated response. It is necessary, in fact, to provide an agency not only with prerogatives of direction and control, but also with effective powers of intervention that are, when necessary, substitutive of national failures in emergency management. A control room, therefore, of rapid health intervention and civil protection, with its own budget and operational decision-making, free from the veto of a single state, which can act

quickly, with consistent and coordinated measures, with the ability to collect homogeneous data, with professionally trained and constantly updated staff, with a production capacity—its own or supply—of tested machinery and protective devices, vaccines, and specific drugs. Thus, not only during an emergency, but also in ordinary times, it is desirable to lean on a Preparedness European Agency to share of resources and data, with harmonization of public health and social measures for response. Such a network would assure and promote accountability by synthesizing, reviewing and assessing operative information and knowledge, and for critically evaluating the effects of public health decisions. Basically, also to try to overcome the gap, which currently exists, between the time when there is awareness of a critical emergency event and the unharmonized decisions to effectively prevent, halt, or delay the consequences of this event. Considering the Italian situation, despite the health regionalism, it is necessary to identify an adequate "chain of command", able to exercise a leadership role to coordinate and integrate the skills of all institutions and actors involved, on whose collaboration lies the readiness to respond and the resilience of an integrated system. Finally, the pandemic has highlighted the need to interrupt the continuous defunding of the health sector, allocating funds especially in prevention, training and information activities: indeed, a greater and more aware public attention toward health risks and on the impacts of emergencies can help to promote virtuous changes, to share contents and information that act as a guide for the population.

Table 1. Insights to properly manage a health emergency in Europe.

Insights and Suggestions for Creating A Coordinated Health Emergency Management System in Europe
Establishment of a permanent European infrastructure with the capacity for rapid intervention in the event of a health emergency that may involve more than one European state, with autonomous management of its own budget and funds necessary for intervention and autonomy in operational decision-making, free from the veto of a single state.
Continuous funding and promotion of transnational collaboration, with central governance of emergency management and a task force for rapid local health intervention ("rapid intervention health task force" or RIHTF).
Creation or implementation of central European laboratories for the development of research and prevention, diagnostic and therapeutic methods to combat infectious and/or toxicological agents, or governance of the European network for the surveillance of communicable diseases (ECLDC).
Implementation of the real-time surveillance network, through digital tools and data interoperability, between States and Local Authorities.
Increasing the resilience of national and regional health systems through the development and adoption of predictive models and methodologies for risk assessment and quantification, and the study of harmonized decision-making processes that can be unambiguously adopted across EU countries.

Author Contributions: Conceptualization, L.A., F.D., L.V., W.R., G.D., P.L., M.R.G. and U.M.; Methodology, L.A., L.V., M.F.R., A.D., C.A., M.R.G. and U.M.; Investigation, L.A., F.D., L.V., L.A., L.V., F.D., M.R.G., U.M., L.A. and L.V.; Writing—Review and editing, L.A., L.V. and M.R.G.; Visualization, L.A., F.D., L.V. and M.R.G.; Supervision, W.R., M.R.G., G.D., P.L. and U.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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ISBN 978-3-0365-6056-4