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ГРАФІК ПІДГОТОВКИ КВАЛІФІКАЦІЙНОЇ/МАГІСТЕРСЬКОЇ РОБОТИ ДО ЗАХИСТУ

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2.	Вивчення джерел літератури, матеріалів архівів, періодичних видань, збір та узагальнення фактів, даних	жовтень -листопад	13 листопада		
3.	Складання плану кваліф. роботи та узгодження її з науковим керівником	листопад	13 листопада		
4.	Написання розділів роботи *або* постановка експерименту, аналіз отриманих даних наукового дослідження	листопад - березень	25 березня		
5.	Проміжний контроль виконання роботи	лютий	17 лютого		
6.	Написання кваліфікаційної роботи в цілому, ознайомлення з її першим варіантом наукового керівника	січень - березень	25 бререзня		
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	Розділ 2 (аналітично дослідницька частина) (експериментальна частина для природничих та біологічних наук)				
	Розділ 3 (проектно-рекомендаційна частина) (аналіз результатів для природничих та біологічних наук)				
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ЗАВДАННЯ

ДЛЯ КВАЛІФІКАЦІЙНОЇ/МАГІСТЕРСЬКОЇ РОБОТИ СТУДЕНТА

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TABLE OF CONTENT

LIST OF ABBREVIATIONS 5

ABSTRACT 7

ACKNOWLEDGMENTS 8

INTRODUCTION 9

CHAPTER 1. STRENGTHENING EMERGENCY MEDICAL SERVICES: LITERATURE REVIEW 12

1.1. Why to Focus on Emergency Medical Services? 12

1.2. Methods of Evaluation of Emergency Medical Services 14

1.3. Risk Factors of Emergency Medical Systems 17

CHAPTER 2. METHODOLOGY 20

2.1. Study Settings 20

2.2. Study Participants 21

2.3. Classification of Variables Used in the Study 22

2.4. Data Sources and Measurement 25

2.5. Potential Biases 26

2.6. Study Size 26

2.7. Statistical Methods 27

CHAPTER 3. RESULTS OF EMS SYSTEM REVIEW WITH WHO'S SIX BUILDING BLOCKS 30

3.1. Emergency Medical Services Leadership and Governance in Ukraine 30

3.1.1. Organisational Structure of Emergency Medical Services 30

3.1.2. Leadership in the Ukrainian Emergency Medical Services 32

3.2. Emergency Medical Services Delivery Infrastructure 32
3.2.1. Demand for Emergency Medical Services 32
3.2.2. Emergency Medical Services Response Time 33
3.3. Emergency Medical Services Financing 34
3.4. Emergency Medical Services Workforce 35
3.5. Emergency Medical Services Information and Communication Technologies 38
3.5.1. Activation of Emergency Medical Services 38
3.5.2. Collection of Emergency Medical Services Operational Data 38
3.6. Emergency Medical Services Essential Medicines and Equipment 39
3.6.1. Emergency Medical Services Fleet 39
3.6.2. Emergency Medical Services Fleet Utilization 39
CHAPTER 4. RESULTS OF CASE-CONTROL STUDY 41
4.1. Study participants 41
4.2. Descriptive and outcome data 43
4.3. Crude and Adjusted Logistic Regression Models 46
4.4. Additional analysis of missing values 50
CHAPTER 5. DISCUSSION 53
5.1. EMS System Building Blocks Key Findings and Interpretation 53
5.1.1. Irrational Use of Limited EMS Resources 53
5.1.2. Inequalities in State Funding for the Oblast EMS Centers 56
5.1.3. Variation in the Utilization of EMS Fleet 57
5.1.4. Skewed Distribution of EMS Workforce 58
5.2. Case-Controls Key Findings and Interpretations 59
5.2.1. Readiness of Emergency Medical Services to Respond 59
5.2.2. Timely Response Improves Outcomes 60

5.2.3. An Emergency in a Public Place is a Risk for Mortality During EMS Care 61
5.2.4. The Need for Call Categorisation 62
5.2.5. Use of Physicians on Ambulances 62
5.3. Study Limitations 63
5.4. Generalisability of Findings 64
CONCLUSION 66
Recommendations 68
REFERENCES 70
APPENDIX A. LIST OF TABLES 82
APPENDIX B. LIST OF FIGURES 83
APPENDIX C. LETTER FROM VINNYTSIA EMERGENCY MEDICAL SERVICES CENTER 84

LIST OF ABBREVIATIONS

AED - Automated external defibrillator

AOR - Adjusted odds ratio

CI - Ninety-five percent confidence intervals

CV - Coefficient of variation

DALY - Disability-adjusted years of life

EMS - Emergency medical services

HCF - Health care facility

HIC - High-income countries

IQR - Interquartile range

LMIC - Low- middle- income countries

MAR - Missing at random

MoH - Ministry of Health of Ukraine

NHSU - National Health Service of Ukraine

OR - Odds ratio

PHC - Primary health care

SD - Standard deviation

STROBE - Strengthening the Reporting of Observational Studies in Epidemiology

UAH - Ukrainian Hryvnia

UHU - Unit hour utilization

USPCEMDM - Ukrainian Scientific and Practical Center for Emergency and Disaster Medicine

Vinnytsia EMS Center - Communal Nonprofit Enterprise Vinnytsia Oblast Center of Emergency and Disaster Medicine

WHO - World Health Organisation

ABSTRACT

Background: Emergency medical services (EMS) in Ukraine are currently under increased scrutiny for the quality of care that they provide. The Government initiated a set of policies to reform the EMS system. This study aimed to evaluate the EMS system to provide evidence-based recommendations for its improvement.

Methods: A matched case-control study was used to determine risk factors associated with death during prehospital care. Vinnytsia oblast EMS dispatch center data was used to identify 898 patients that died during EMS care (cases), from January 17th, 2017 to June 19th, 2019. Each case was paired with a control patient (matched on age and chief complaint). A binary logistic regression was used to determine the association of risk factors with prehospital mortality.

Results: The study found that ambulance response time (adjusted odds ratio 2.417; 95% confidence intervals 1.667 - 3.505; $p = <0.001$) and place of incident (adjusted odds ratio 2.658; 95% confidence intervals 1.661 - 4.254; $p = <0.001$) are associated with increased risk of mortality.

Implications: The study discussed possible explanations of increased mortality and proposed strategies aimed at its reduction. However, further research is needed to investigate other factors that can potentially influence the mortality of patients in emergency conditions.

Keywords: EMS; prehospital mortality; case-control; response time

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INTRODUCTION

The emergency care system in Ukraine is part of the publicly funded healthcare system, it includes both prehospital emergency medical services and facility-based emergency care, and it is mandated to respond to medical emergencies by law [1]. The Ukrainian emergency medical services (EMS) system has faced many challenges with regards to management, resources, trained personnel, and quality of care [2–5]. A few years ago, in light of the national health finance reform that began in 2017, a set of policies were proposed by the Ministry of Health (MoH) to improve the Ukrainian EMS [6,7]. More recently, in 2019, the President of Ukraine issued an order on reform priorities, where he emphasized the need for further improvement of the emergency medical services [8]. Given that a limited amount of evidence exists on the performance and outcomes of the current Ukrainian system, it is critical to ensure that such evidence is available to support the efforts of decision-makers to improve the delivery of EMS in Ukraine [9,10].

It has been concluded by the World Health Organisation (WHO) that a major limiting factor for the creation of evidence on EMS performance in Ukraine has been an absence of reliable operational data [10]. Within the health finance reform, the National Health Service of Ukraine (NHSU) established a set of requirements for EMS providers that they need to comply with in order to receive national funding for their services [11]. One of the requirements is that each EMS center must have a centralized computer-aided dispatch system that submits operational data to the national data repository (Central 103) [11,12]. The NHSU can later use this data to evaluate the performance of each EMS center [13]. This data also provides an opportunity for further studies aimed at improving patient outcomes across the EMS system in Ukraine.

As of April 1st, 2020, all EMS Centers in Ukraine are financed by the NHSU and therefore have a centralized computer-aided dispatch system or are in the process of building one [10]. The Vinnytsia oblast EMS Center was one of the first among all

Ukrainian EMS centers that established such a system [14]. Hence, it possesses the largest amount of reliable data on both performance and outcomes of EMS systems on the oblast level.

This study employed a case-control methodology with the aim to investigate risk factors associated with death during EMS care, using the data from the Vinnytsia oblast EMS dispatch center [15]. The study also describes the national EMS system's utilization of the WHO Health System Building Blocks framework [16,17]. The findings of this study aim to provide reliable evidence that can be used to inform policy formulation on Ukrainian EMS system improvement.

Therefore, *the object* of the study is defined as the Ukrainian EMS system. *The subject* of this study is the risk factors associated with death during EMS treatment in Vinnytsia oblast.

The following *tasks* were made for the study:

1. Analyze the Ukrainian EMS system using the WHO's Health System Building Blocks framework.
2. Conduct a case-control study of risk factors associated with mortality in the prehospital stage of the emergency care system in Ukraine.
3. Compare EMS delivery in Ukraine with other countries.
4. Develop a set of recommendations to decrease mortality in the prehospital stage of the emergency care system in Ukraine.

The study used the following predefined hypotheses:

1. The patient's sex is associated with an increased risk of death during prehospital care.
2. The risk of dying during prehospital care varies by season, with greater risk during winter.
3. Patients seeking emergency care outside working hours are at a greater risk of death during the provision of care.
4. Patients treated by a physician lead crew have less risk of dying during care.

5. The risk of dying during prehospital care does not differ between patients that are classified by dispatch as urgent and non-urgent.
6. Patients that reside in rural areas are at a greater risk of dying during care.

CHAPTER 1. STRENGTHENING EMERGENCY MEDICAL SERVICES: LITERATURE REVIEW

During the Seventy-second World Health Assembly, Member States agreed that "a functional emergency care system is essential to universal health coverage, and investing in frontline care saves lives, increases impact and reduces costs in other parts of the health system" [18]. The emergency care system responds to a wide range of acute conditions for people of all ages, such as trauma, infectious diseases, emergencies in pregnancy and exacerbations of noncommunicable diseases [19,20]. The WHO Emergency Care System Framework outlines the following core functions of the system: timely recognition of an emergency, provision of prehospital care, transport to the facility-based emergency department, and initiation of early operative and critical care [21]. The literature review will examine why it is important to focus on improving EMS in Ukraine, as well as, highlight key methods used for the evaluation of EMS internationally.

1.1. Why to Focus on Emergency Medical Services?

Well organized EMS is an effective measure to be taken to improve health outcomes across a range of emergency conditions. A recent World Bank report on Disease Control Priorities estimates that over half of the deaths and forty percent of the total burden of disease in low- middle- income countries (LMIC) are caused by conditions that require EMS care [22]. A robust evidence, from both LMIC and high-income countries (HIC), proves that a well organised system is an effective measure to reduce that burden. For example, several studies found that a better-organized trauma care system can decrease preventable death from injury by over fifty percent [23]. Another study suggests that, if recognition and treatment of myocardial infarction are done within the first sixty minutes, it can reduce mortality up to three times [24]. Furthermore, obstetrics disorders that are responsible for over half of all maternal deaths in the world, such as hemorrhage, hypertensive disorders, and sepsis, are effectively treated by EMS care, if administered timely [25,26].

The emergency medical services, in addition to being an effective measure, have been found to be a cost-effective measure in improving outcomes and lowering the burden of diseases across many conditions [22,27–31]. A study done in the United States calculated the cost of EMS per year of life saved, including personnel, equipment, training, and infrastructure costs. These EMS costs were later compared to other disease-specific programs and the EMS was found to be the most cost-effective among all programs that were included in the study [27]. Another study, conducted in Germany, suggests that investing in a physician-staffed ambulance service has a cost-effectiveness ratio high [28]. Moreover, a study from the Indian emergency care system suggests that giving aspirin to people with suspected myocardial infarction has the minimal cost per Disability-Adjusted Life Year (DALY) averted [29]. Therefore, interventions to improve emergency care are effective and affordable, specifically for countries with a limited healthcare budget, like Ukraine.

Despite such proven effectiveness and cost-effectiveness of EMS care, many LMIC struggles to organize their EMS systems to perform at the required levels, including in Ukraine [4,10,22,32]. These systems often fail to organize basic components of EMS, such as ensuring that the system is able to timely recognize and respond to emergencies, have designated emergency departments, and provide appropriate training to healthcare providers at all levels [33]. The lack of organized emergency care in many LMIC leads to wide discrepancies in outcomes across the range of emergency conditions [22,34]. This means that people with similar severity of injury or illness are much more likely to die in LMIC than in HIC. For example, the risk of dying from diabetic ketoacidosis is 30 times greater in LMICs than in HICs [35,36].

Without a well functioning EMS system, any interventions that are made to expand the availability of disease-specific treatments will be compromised. If a critical link is not provided by the EMS between the place of the emergency and definitive care, then patients will be unable to reach the definitive care they need, even if such care exists in another part of the healthcare system [22,37]. Therefore, even the most modern and effective disease-specific treatments will be inaccessible to patients in emergency conditions, if there is no well functioning EMS.

The EMS is also a critical component of ensuring preparedness and response to major natural or human-made disasters or conflicts, as well as, safety during mass gathering events [38,39]. Hence, it is paramount for Ukraine to have a well organized EMS system, to respond to any of those situations. Especially given the ongoing armed conflict in Eastern Ukraine, a history of mass protests, and extreme weather events [40].

To summarize, the EMS system is both an effective and cost-effective measure to mauve populational outcomes. Thus, the increased scrutiny that the Ukrainian EMS has received in recent years is beneficial for improving patient outcomes. However, prior to initiating the reform, the system needs to be evaluated, so as to be able to understand what needs to be improved and what works well [41].

1.2. Methods of Evaluation of Emergency Medical Services

There are many strategies that aim at evaluating the health system, in order to determine what needs to be improved for the more effective and efficient performance of the system. Some use various quality indicators to monitor performance and outcomes, while others utilize a more holistic health system evaluation approach [16,41,42].

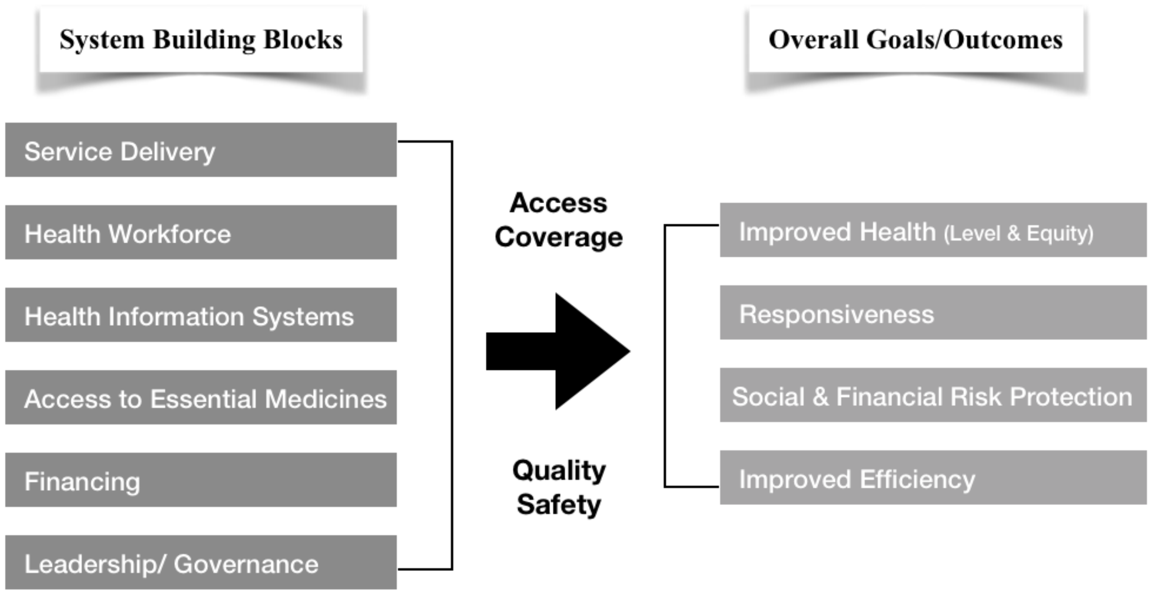
A recent literature review of quality indicators for prehospital EMS, identified 25 studies with over 300 different quality indicators [43]. Generally, all of those indicators can be categorized into three groups: (1) structural indicators, (2) process indicators, and (3) outcome indicators. The structural indicators aim at the evaluation of resources available in the health system, as well as their distribution. The structural indicators may include the number of ambulances, the quantity of the health workforce, and the availability of equipment. The advantage of these types of indicators is that it is relatively easy to measure and monitor them [44]. However, it is noted that these indicators are indirect measures of quality. Sometimes they lack association with patient outcomes, and it is difficult to link them to specific parts of the system that require improvement [45].

The process indicators aim at measuring the "sequence of steps in patient care intended to improve patient outcome" [45]. The most frequently used process indicator in EMS is the response time and other time intervals [46,47]. Process indicators can also measure clinical aspects of care, such as the percent of patients with suspected myocardial infarction who were given aspirin or transported to the most appropriate health facility [45]. This type of indicator provides specific input for improvements, however with more complex treatments they can get too complex to measure and interpret.

The outcome indicators, as defined by the Emergency Medical Services Outcomes Project are set to monitor changes in health that are related to: (1) death, (2) disease, (3) disability, (4) discomfort, (5) dissatisfaction, (6) destitution [48]. Examples of such indicators may include the success rate of out-of-hospital cardiac arrest resuscitation, trauma mortality, or even patient satisfaction. These indicators give direct feedback on the performance of all components of the system, as well, they are easier to understand. They also allow for further, more robust scientific evaluation of system performance that is linked to outcomes [48].

Another approach to measuring health system performance is proposed by the WHO [16]. This approach aims to unite numerous indicators into one common system. It is built around the WHO framework of six essential components of the health system: (1) service delivery, (2) health workforce, (3) health information systems, (4) access to essential medicines, (5) financing, and (6) leadership and governance (Figure 1) [49]. The WHO recommends monitoring these building blocks in order to strengthen the health system and improve: (1) health, (2) responsiveness, (3) social and financial protection, and (4) efficiency. Moreover, this approach has been successfully adapted to use in the EMS system evaluation [17]. Therefore, to describe the Ukrainian EMS system for this study, the WHO proposed framework was used in combination with some widely accepted structure, process, and outcome indicators on which data was available.

Figure 1.1. WHO Health System Buildings Blocks



Adapted from: [16]

Another approach to evaluating and improving the EMS system performance goes beyond simple measurement and reporting of indicators. If sufficient data is available, then epidemiological methods can be applied to study associations between different exposure factors and patients' outcomes. The exposure factors can include the use of different treatment options, socio-demographic characteristics of the patient population, differences in system designs and processes, as well as ambient factors. All of these factors may influence patients' outcomes within the system [50]. In these methods, a patient's mortality or disability are usually used as outcome measures. By determining factors that are strongly associated with increased mortality or disability, precise recommendations can be made for their improvement [51].

The Vinnytsia Oblast EMS Center was one of the first in Ukraine to install a computer-aided EMS dispatch system. Thus, it already has a sufficient amount of reliable data in its registry, both on EMS performance and patient outcomes. This provides an opportunity to employ epidemiological methods to assess the system's performance on patient outcomes. One of the epidemiological methods suitable for this purpose is a case-control study, as it has been widely used in similar settings by other researchers [52–55]. The results of such a study will provide evidence-based recommendations on how to improve the outcomes of patients treated by the EMS system in Vinnytsia oblast. Furthermore, the recommendations can be generalized to other similar oblasts across Ukraine.

1.3. Risk Factors of Emergency Medical Systems

To conduct a case-control study aimed at investigating risk factors for mortality on the prehospital stage, one needs to understand what are the potential factors that can influence patient outcomes. This section will review published literature to determine which of the variables present in the Vinnytsia EMS Dispatch data can be classified as exposure factors and confounders.

Ambulance response time is one of the most studied exposure factors that can influence prehospital outcomes. A population-based study with over 2000 motor vehicle collision deaths concluded that prolonged ambulance response time is associated with an increased risk of mortality [56]. Another study of trauma patients found that with every ten minutes delay in care, the odds of mortality increases by four percent [57]. Moreover, the prolonged response time is not only dangerous for trauma patients, but also for patients with cardiac emergencies and other medical conditions [24,46,58,59]. However, contrary to these findings, opposing points of view also exist. As one study assessed outcomes of patients that received ambulance attention before and after 10 minutes and did not find any significant difference [60]. Although, this study did not assess more significant delays in the response, as it was conducted in a well developed EMS system.

Published evidence also suggests that the location of an emergency can potentially influence outcomes of severely ill or injured. A recent systematic literature review that included 31 different studies concluded that patients suffering from trauma or out-of-hospital cardiac arrest, living in an urban setting have higher survival rates than patients in rural settings [61]. The discrepancy in outcomes was mainly attributed to better access and quality of care in urban settings. Moreover, it has also been studied that outcomes of patients with out-of-hospital cardiac arrest may vary depending on the exact place of the emergency, whether this is a public place or a private location [62,63]. Therefore, both urban/rural settings and private/public locations can be treated as potential exposure factors.

Seasonal and temporal factors also have the potential to influence patient outcomes. Several studies found significant variation in demand for EMS by day of the week and time of the day [64,65]. Moreover, another study detected a similar variation in the number of patients seeking emergency care by the season of the year [66]. With the majority of patients referring to emergency care with trauma during the summer months. Thus, the access and quality of service can be affected in the times when the supply of services does not meet the demand and this can negatively influence patient outcomes.

The use of physicians in ambulance care has long been debated, both in the literature and in practice. A pilot study of the use of physicians on ambulances in Sweden concluded that the advanced skills of physicians are often either not required or cannot be performed at the prehospital stage [67]. At the same time, many other studies found that the presence of physicians on the ambulance can significantly improve outcomes of patients with out-of-hospital cardiac arrest, major trauma, and respiratory failure [68,69]. As the Ukrainian EMS system uses both physician and feldsher lead ambulances, this can be considered as another factor that can potentially influence outcomes.

The response time and level of care (use of a physician) for a particular case are dependent on the urgency of the call that is assigned by the dispatch center. Hence, it is paramount for the dispatchers to be able to accurately categorize which calls need immediate response and which can be delayed, so as to not overwhelm the system. Many dispatch centers around the world have started using specialized software that can assist dispatchers to assign the category of the calls [70,71]. Such software has been proven to be extremely effective [72,73]. Regardless of the availability of such software, the Ukrainian EMS still heavily relies on the decisions of the dispatchers to determine the category of the calls [10]. Therefore, the priority of the call that is assigned by the dispatcher can be another factor that influences patient outcomes in the Ukrainian EMS system.

Another factor that can determine outcomes is the patient’s sex. One study found that male patients have a significantly higher risk of dying from out-of-hospital cardiac arrest than females (odds ratio (OR) 1.826; 95% confidence intervals (CI) 1.182 - 2.821) [74]. A similar association was detected in trauma patients [75,76]. One study even concluded that male patients had almost 50 percent more chances of dying than females (OR, 1.49; 95% CI 1.39 – 1.59) [75].

Patients’ age and medical conditions (chief complaints) can be considered as confounders as they often influence both the likelihood of outcomes and the exposure factors. Studies suggest that age contributes to the occurrence of different diseases, as well as can influence the chances of survival [53]. Similarly to age, medical conditions can also determine the magnitude of some of the exposures, as well as the likelihood of mortality [77]. Therefore, to eliminate such confounding, only patients with similar conditions and age should be compared between themselves. This can be achieved by performing a matching of these factors [78].

In summary, by reviewing the literature, potential risk factors and confounders to mortality during prehospital treatment were identified. The risk factors include ambulance response time, location of the incident, time and season of the incident, level of care provided by the ambulance crew, urgency of response determined by the dispatcher and the patient’s sex. While potential confounders for an analysis on mortality during prehospital care are the patient's age and chief complaint.

CHAPTER 2. METHODOLOGY

The main study aims to determine the risk factors (exposures) associated with mortality during prehospital care (outcome). For this, a case-control methodology was used [15]. The data for the cases and controls were taken from the Vinnytsia EMS Centralized Dispatch Center, for the period of January 17th, 2017 to June 19th, 2019. Information on exposures was taken from different call characteristics, which were contained in the dispatch registry for both the cases and controls. Similar to other studies of mortality in emergency care that use secondary data [52,53,76]. To minimize the confounding effects of age and the patient's chief complaint, cases were matched to controls in a one to one ratio. The study methodology and results were reported with the use of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations [79].

To better interpret the results of the main study focused on risk factors, the Ukrainian EMS system was initially assessed, using a holistic health systems approach. The World Health Organization's 'Six Building Blocks of a Health System' framework, along with published recommendations on how to apply them for the assessment of EMS systems, were used for the assessment [17,49] Necessary information for the system assessment was collected through a desktop review of available government statistics, regulations and published literature. The results of the health system assessment are presented in chapter three.

2.1. Study Settings

Vinnytsia oblast has a total territory of 26.5 thousand square kilometers, which is divided into 27 administrative districts. The population of the Vinnytsia oblast is over 1,535,714 people, with 51.4 percent living in urban settings and 48.6 percent living in rural settings [80]. The majority of medical emergencies that happen in Vinnytsia oblast are addressed by the public EMS service. Vinnytsia region has one public provider of EMS care, which is the Communal Nonprofit Enterprise Vinnytsia Oblast Center of Emergency Medical Care and Disaster Medicine (Vinnytsia Oblast EMS Center).

The study used secondary data obtained from Vinnytsia Oblast Centralized Computer-aided EMS Dispatch Center (Vinnytsia EMS Dispatch Center). To access the data from the Vinnytsia EMS Dispatch Center registry, official requests for public information were sent to the Vinnytsia Oblast EMS Center, as per the Ukrainian Law on Access to Public Information [81]. The EMS Center provided required anonymized data, in electronic format. The official correspondence with the Vinnytsia oblast EMS Center is shown in Appendix A to this study.

The data provided by the Vinnytsia Oblast EMS Center contained all calls that the Vinnytsia EMS Dispatch Center received during the period from January 17th, 2017 to June 19th, 2019. Part of the information in the data was imputed by the EMS dispatcher that received the calls, such as: (1) patient's age; (2) sex; (3) chief complaint; (4) location; and (5) the urgency of the call. Some of the information was also inputted by the ambulance crew that was dispatched to the call, such as (1) time of contact with the patient; (2) patient's condition; (3) results of the response; (4) hospitalization status; and (5) place of incident. Another part of the information was generated automatically, such as: (1) call ID; (2) time of the call; (3) timestamp of the beginning of the response; and (4) timestamp of the end of the response.

2.2. Study Participants

To identify the study participants' chief complaint, inclusion criteria were applied to the data from the Vinnytsia regional Centralized EMS Dispatch Center. Therefore, only participants with the following chief complaints were selected: cardiac emergency, acute poisoning, diabetic emergency, acute allergy, bleeding, difficulty breathing, pain syndrome, stroke, seizures, and trauma. Consequently, all calls to Vinnytsia regional Centralized EMS Dispatch Center with the following code were excluded: sick persons, death examination, interfacility transports, and unconsciousness.

Complaints of a 'sick person' and 'unconsciousness' were excluded, because they can be caused by a wide range of medical conditions. Without a more precise understanding of the underlying medical condition, it is not possible to draw any conclusion from comparing cases to controls. For example, a 'sick person' code can be assigned to patients with either poisoning, influenza, or with cardiac complaints. Similarly, unconsciousness can also have many causes.

All records of ambulances being deployed for 'interfacility transports' or 'death examination' were also excluded, as those calls were not an emergency and are therefore not of interest to this study. After applying the eligibility criteria to the data set, the cases and controls were identified. Cases in this study were all patients that were treated by the Vinnytsia EMS and died during treatment. Controls were taken from the same data set from the Vinnytsia EMS for January 17th, 2017 to June 19th, 2019, but the patients in the controls did not die during prehospital treatment.

2.3. Classification of Variables Used in the Study

This section provides a definition of all outcomes, exposures, and confounder variables included in the analysis to test the study hypothesis. The selected outcome is death during prehospital treatment, while the exposure factors are the response time, the season during which the response took place, time of the response, level of care, priority of the call, location of patient residence, and patient's sex. The patient's sex and chief complaint were identified as confounders. The rationale for the selection is provided below.

For the purpose of this study, the variable containing the results of the response has been chosen as the outcome variable. This variable contains information provided from the electronic medical records that were filled by the ambulance crew during the call. This variable indicates whether the patient's condition improved, worsened, or remained the same aftercare was provided by the ambulance crew. Additionally, the ambulance crew noted in this variable if the patient died before the arrival of the ambulance or during care. Because this study aims to investigate the risk factors associated with mortality during EMS prehospital treatment, mortality was chosen as an outcome. Factors of this variable were recoded to have patients that died during prehospital care in one group (cases) and all other patients in the other group (potential controls).

The study dataset contained several timestamps from which the ambulance response time and season of the response were derived. The response time was calculated by subtracting the timestamp of when the ambulance crew reached the place of the incident form the timestamp of when the dispatcher received the call. As has been noted in other studies, the time of the ambulance response is a significant exposure factor for many emergency conditions [24,56,57]. Therefore, we chose the time of ambulance response as one of the exposure factors that may be associated with the outcome of interest. From the timestamp of when the dispatcher received the call, the season of the year and time of the day was derived and coded as a factor variable. According to the study hypothesis, we divide the year into the following four seasons to investigate associations between season and the outcome: Fall (from September, 15th to December, 15th); Spring (from April, 15th to June, 15th); Summer (from June, 15th to September, 15th); and Winter (from December, 15th to April, 15th). Similarly, to a study that assessed seasonal demand for emergency department use [58].

One of the hypotheses of this study is that the time of the emergency may potentially influence the outcomes. Specifically, it has been studied that depending on the time of the emergency, patients may have different access to timely ambulance care [64]. This may be due to factors such as increased traffic during working hours, due to which ambulances take longer to arrive to the patient and to transport the patient to the hospital. Also, during the night, there may be fewer ambulances available. To investigate the association of the time of the day and the outcome, the day was divided into the following factor categories: from 00:00 to 05:00; from 05:00 to 11:00; from 11:00 to 16:00; from 16:00 to 19:00; and from 19:00 to 24:00.

The level of care provided is considered as another variable that may influence the outcomes. A way of measuring the level of care provided is to consider whether a physician lead crew would potentially provide a higher standard of care than a feldsher lead crew [67,68]. Therefore, as another exposure factor for the analysis, we included the variable with the type of crew that responded to the incident. This variable contains the following levels: physician lead, feldsher lead, other, and unknown. For the purpose of this study, different types of specialized ambulance crews were recoded into the category 'other', because their numbers were scarce. The specialized crews in Vinnytsia Oblast EMS Center include: cardiac units, physiological units, and pediatricians.

Another exposure factor that was included in the analysis is the priority of the call. The study hypothesizes that the patients identified as a higher priority by the dispatcher will receive care more promptly and with a higher standard, and will, therefore, have fewer chances of mortality while receiving prehospital EMS care. The priority of the call is assigned by the dispatcher without the use of specialised software [10]. Vinnytsia EMS Dispatch Center uses two call categories, urgent and non-urgent. As some of the calls had no priority assigned to them, they were coded in a separate group named 'no priority', so as to be included in the analysis.

The next exposure factor included in the study is the location of the patient's residence, as there were patients living in both urban and rural areas included in the data. The location may have a significant impact, as those patients living in rural areas often have poorer coverage with emergency services and thus may have worse outcomes [61]. The information was collected and recorded by the crew that responded to the incident and was categorized as one of three possible locations of residence: urban, rural, and international.

There have been many studies conducted that have identified that the sex of the patient as a significant exposure factor for death from emergencies, in the prehospital stage [74–76]. Therefore, this study takes into account the sex of the patient as another exposure factor, using the data provided from the study dataset. There are three levels that are used to identify the sex of the patient: male, female, and unknown.

The study identified two key confounders, that may determine the chances for a patient to obtain a specific outcome. These two confounders are the patient's chief complaint and the age of the patient. The patient's chief complaints is a confounder, as it has been shown by other research that patients with different emergencies have different chances of dying during prehospital care [73]. For example, patients with cardiac complaints may have a far higher chance of mortality than patients with acute poisoning. The age of the patient was selected as the other confounder, as some studies confirm that there is a strong association between the age of the patient and the odds of their survival [53].

In order to address confounding by age and chief complaint, frequency matching by age, and chief complaint of cases to controls was performed with a one to one ratio. If there was more than one match of controls to cases, only one control was chosen randomly. Random selection was done with replacement, as this is the preferred method to optimize odds of source population being selected as controls [82]. Performing this matching allowed us to better measure the causal effect of exposure to outcome.

2.4. Data Sources and Measurement

Data for all cases and controls were obtained from one Vinnytsia EMS Dispatch registry from January 17th, 2017 to June 19th, 2019. The registry collected data in the same format and with the same level of measurements for both cases and controls. All variables, except age and response time are categorical variables.

The response time was calculated by subtracting the timestamp of when the dispatcher received the call from the timestamp when the ambulance crew reached the patient. The response time was measured in minutes. The age was reported either by the patient or by the person who called the ambulance and was recorded by the dispatcher. For the purpose of this study, all patients whose age was less than one year and noted in the registry as the number of months were rounded up to one year. Therefore, the age variable is measured in years and only recorded as natural numbers. Both the age and the response time variables were handled in the analysis as continuous variables.

2.5. Potential Biases

One of the potential biases in the study that may undermine external validity is the selection bias [83]. Selection bias may arise due to missing values on variables that the matching was performed (age and chief complaint). Specifically, approximately five percent of the controls did not have data on the age variable. Therefore, as only controls with no missing age were included in the study, those five percents were excluded. Thus, there is a concern that the selected controls may not be representative of the general population. However, as the number of missing values was relatively small, we worked under the assumption that they were missing at random (MAR), as described elsewhere [84]. To check this assumption, we compared the selected cases to the source population in an additional analysis. We considered that if the additional analysis would not show a major difference between selected cases and the source population, then the assumption was made correctly and the missing values can be excluded without a threat to the external validity of the results.

2.6. Study Size

The size of this study was determined by the number of cases that were recorded in the Vinnytsia EMS Dispatch registry, from January 17th, 2017 to June 19th, 2019.

2.7. Statistical Methods

After the dataset was obtained with permission from the Vinnytsia EMS Center, it was uploaded to the R Foundation for Statistical Computing, based in Vienna, Austria [85]. First, the variables data types were determined. Next, the age variable was standardized, so as to be in years and as a natural number. Then, the response time was calculated by subtracting the time when the dispatcher received the call from the time when the ambulance crew reached the patient, and recorded in minutes.

After the age was standardized and the response time was calculated, the inclusion and exclusion criteria were applied to the dataset. Eligible cases and controls were identified and matched by age and chief complaint. The R script for the matching process is illustrated in Figure 2, for better reproducibility of results.

Once matching was performed, the correctness of it was checked by conducting a comparison of the mean age of cases and controls, using an independent t-test [86]. This test was needed to check whether both study groups have the same age distribution and that the confounding by age was accounted for. To assess the matching of the chief complaint, the Pearson's chi-squared test was performed [87]. The test intended to show that there was no difference in the chief complaints between the study groups, and that the matching had been performed correctly.

Upon the assessment of the matching, the frequency tables of exposure factors were developed using the “Tableone R package”[88]. Continuous variables with normal distribution were summarized by calculating the mean and standard deviation (SD), the continuous variables with skewed distribution were summarized by calculating the median and reporting the 25th and 75th percentiles (IQR). Categorical variables were summarized as the number (n) of a particular category or level, and the percentage from the total of the variable.

Figure 2.1. Matching of cases to controls on age and complaint

```
> #cases and controls splitted into separate data frames
> cases <- subset(disp, disp$cc == "1")
> controls <- subset(disp, disp$cc == "0")
> #cases matched with all controls on age and complaint
> merge<-left_join(cases, controls, by=c("age","comp"))
> # if more then one control matched to case only one is randomly chosen
> merge$chosen <- 0
> set.seed(25)
> merge[-tapply(-seq_along(merge$ID.x),merge$ID.x, sample, size=1),]$chosen <- 1
> # IDs of selected controls and cases splitted into separate data frame
> s.controls <- subset(merge, merge$chosen == "1")
> id.m.controls <-as.data.frame(s.controls$ID.y)
> id.m.cases <- as.data.frame(s.controls$ID.x)
> #additional variables pulled from main dataset to selected controls and cases
> m.controls<-left_join(id.m.controls, disp,  by=c("s.controls$ID.y" = "ID"))
> m.cases<-left_join(id.m.cases, disp, by=c("s.controls$ID.x" = "ID"))
> #cases and controls merged to one dataframe
> colnames(m.cases)[1] <- "ID"
> colnames(m.controls)[1] <- "ID"
> cases.and.controls<-rbind(m.cases,m.controls)
```

Professor Neil Pearce, from the London School of Hygiene and Tropical Medicine, in his work explains the preferred methodologies for analyzing matched case-control studies [78]. He stated that if the number of participants in both study groups, the matched cases, and controls, is sufficiently large, and the exposure factors are sufficiently different, then a non-matched methodology should be used. As participants of this study met both criteria, the standard non-matched methodology was used for the analysis [15].

As a first step, the p-values were calculated to check the difference between the study groups. For continuous variables with normal distribution, the parametric independent t-test was performed [86]. While for skewed distributions, a nonparametric Mann-Whitney U test was performed [89]. To compare the difference between the two groups with categorical exposure factors, Pearson's chi-squared test was performed [87]. A p-value of less than 0.005 was considered statistically significant. The threshold of 0.005

was chosen for better reproducibility of the study, as well as to minimize the false-positive rate of the findings [90].

In the following step, all exposure factors that showed that there were statistically significant differences between study groups were included in the binary logistic regression model, to measure the magnitude of the association between the exposure and the outcome [91]. The first model was used to calculate the crude odds ratio (OR), the 95 percent confidence intervals (CI), and the p-values as the measure of association of each exposure factor individually. For better model performance, all categorical variables were recoded to dummy variables [92]. Additionally, categories with a small number of patients (n = < 8) were combined with other categories or removed. As mentioned previously, continuous variables were not recorded as categorical, rather they were treated as continuous.

All exposure factors that showed a statistically significant association with the outcome were used in the binary logistic regression model to measure adjusted association. For this, odds ratios were calculated with an adjustment for each exposure variable, as well as for the variables used for the matching (the Adjusted Odds Ratio). The CI and the p-values were also reported from this adjusted model.

The data used in this study contained approximately five percent missing values, primarily on the variable of the age of the patients, as mentioned earlier in the 'Potential Biases' section. Because five percent is a relatively low number of missing values, as described previously, the assumption that they were missing at random was made [84]. Therefore, all cases and controls with missing values for the age variable were excluded before matching. All participants from the matched set with missing values on any variable were also excluded before performing binary logistic regression. To check whether the assumption that the missing values are MAR, selected cases were compared to the source population. The MAR assumption was made correctly if the selected cases did not have significant differences from the source population.

CHAPTER 3. RESULTS OF EMS SYSTEM REVIEW WITH WHO'S SIX BUILDING BLOCKS

This chapter presents the results of the desktop review of official EMS documents and statistics, according to the WHO's Health System Building Blocks [16].

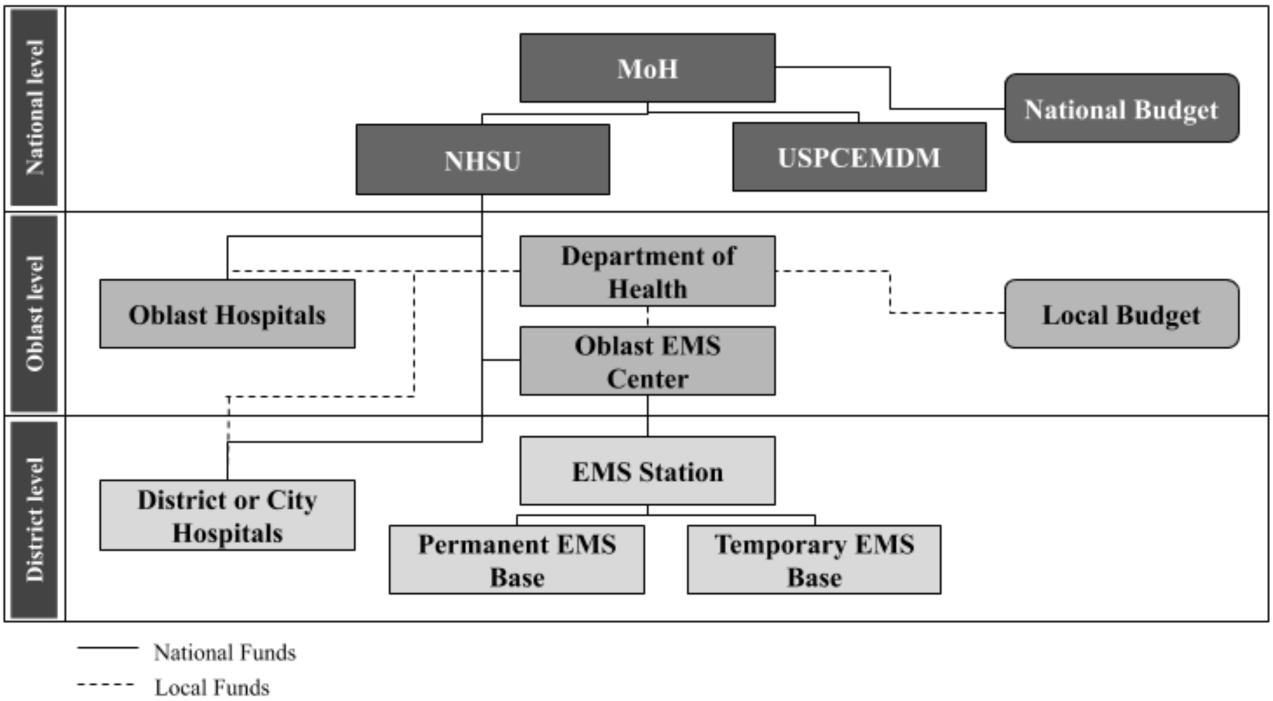
3.1. Emergency Medical Services Leadership and Governance in Ukraine

3.1.1. Organisational Structure of Emergency Medical Services

Prehospital care in Ukraine is coordinated at the oblast (subnational) level [10]. The law on Emergency care, which was adopted in 2012, has assigned administrative and financial responsibilities for prehospital emergency care to EMS centers at the oblast level, moving from a fragmented district-based approach, to a more coordinated oblast approach [93]. Currently, there are 25 EMS centers in Ukraine, one for each oblast, and they are governed by the Oblast Departments of Health of the Oblasts State Administrations (Figure 3).

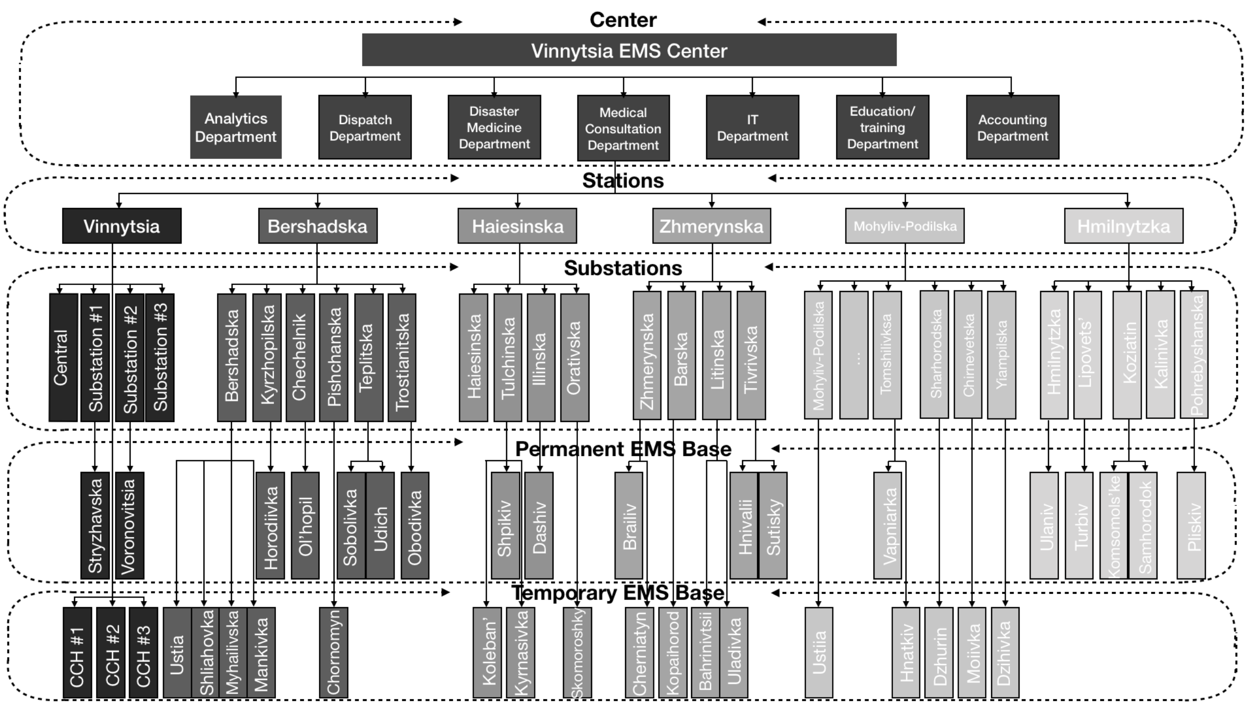
The organisational structure of the oblast EMS center is presented in Figure 4, the example shows the distribution and hierarchy of the Vinnytsia EMS Center. The Center is divided into eight EMS stations that are situated in major settlements across the oblast. Each of the stations oversee from three to six ambulance permanent placement bases that are situated in the smaller settlements. Each of the ambulance permanent placement points may also have an ambulance temporary placement base that is used to decrease the response time.

Figure 3.1. Organisational structure of emergency care system in Ukraine



Adapted form:[10]

Figure 3.2. Structure of the Vinnytsia EMS Center



Adapted from: [94]

3.1.2. Leadership in the Ukrainian Emergency Medical Services

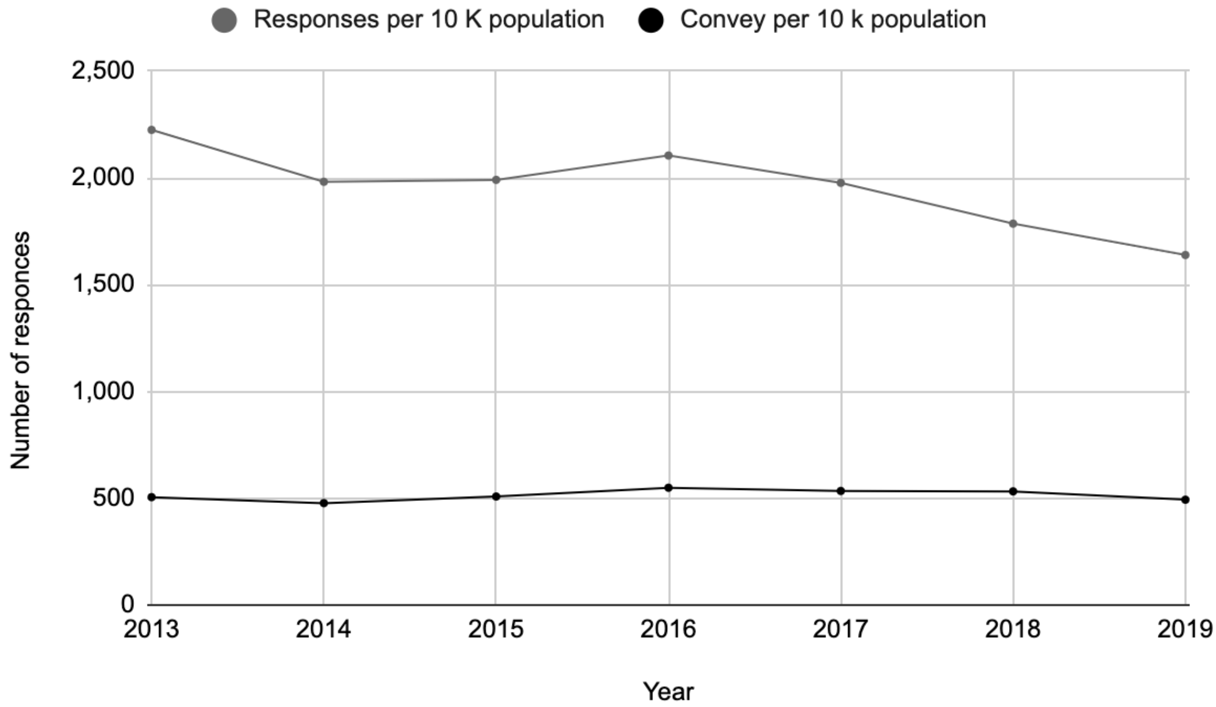
The primary responsibility of overseeing the EMS system lies with the Ministry of Health of Ukraine, which has in its structure a group of experts in emergency medicine. The expert group develops system standards, norms, approves treatment protocols, and formulates policies for system development, through administrative orders of the MoH [95]. Additionally, the MoH owns the Ukrainian Scientific-Practical Centre of Emergency Medical Care and Disaster Medicine (USPCEMDM), which serves as the leading EMS agency in Ukraine [96]. The USPCEMDM is primarily responsible for the collection of EMS statistics, conducting research, measuring quality indicators, assisting the MoH in the development of EMS standards, and providing technical advice to the MoH regarding EMS policy.

3.2. Emergency Medical Services Delivery Infrastructure

3.2.1. Demand for Emergency Medical Services

In 2019, the Ukrainian EMS system received a total of 8,059,161 calls (1,923 per 10,000 population), among them, an ambulance response was required in 85.2 percent of the cases (n = 6,868,961 or 1,639 per 10,000 population). Only about 30 percent of ambulance responses lead to hospitalisation (n = 2,065,585 or 493 per 10,000 population [97]. Over the last seven years, the demand for emergency services has been gradually declining (Figure 5). In 2013, the EMS responded to 2,225 per 10,000 population, while in 2019 only to 1,639 per 10,000 population. However, the number of conveys remained almost the same over the years.

Figure 3.3. Number of EMS responses and conveys per 10,000 population



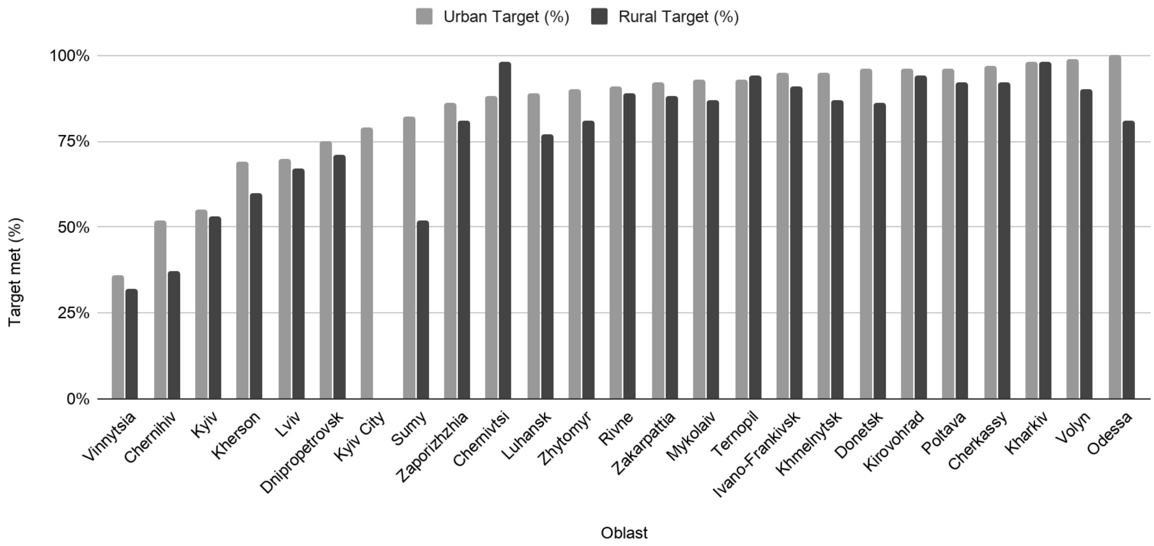
Adapted from: [97]

3.2.2. Emergency Medical Services Response Time

The required EMS response time to urgent calls in Ukraine is 10 minutes in urban areas and 20 minutes in rural areas, and up to two hours for non-urgent calls. The current data shows that 67.5 percent of urban calls meet the response time standard, while only 85.2 percent of the rural calls meet this standard [97]. However, these numbers are difficult to validate given that the statistics are collected on paper.

Figure 6 provides a regional view of this data, showing moderate variation from region to region (CV of 20 percent for urban and 24 percent for rural). The lowest level of urban calls meeting the response time standard of 10 minutes or less occur in Vinnytsia (36 percent), while the highest level is in Odesa (100 percent). The lowest level of rural calls meeting the relevant standard of 20 minutes or less (excluding Kyiv City which has no rural areas) in Vinnytsia (32 percent), while the highest level is in Kharkiv (98 percent). The caution noted earlier about the absence of a computerized dispatch system should be restated here with respect to this data.

Figure 3.4. Percentage of calls meeting response time standards by region in 2019



Adapted from: [97]

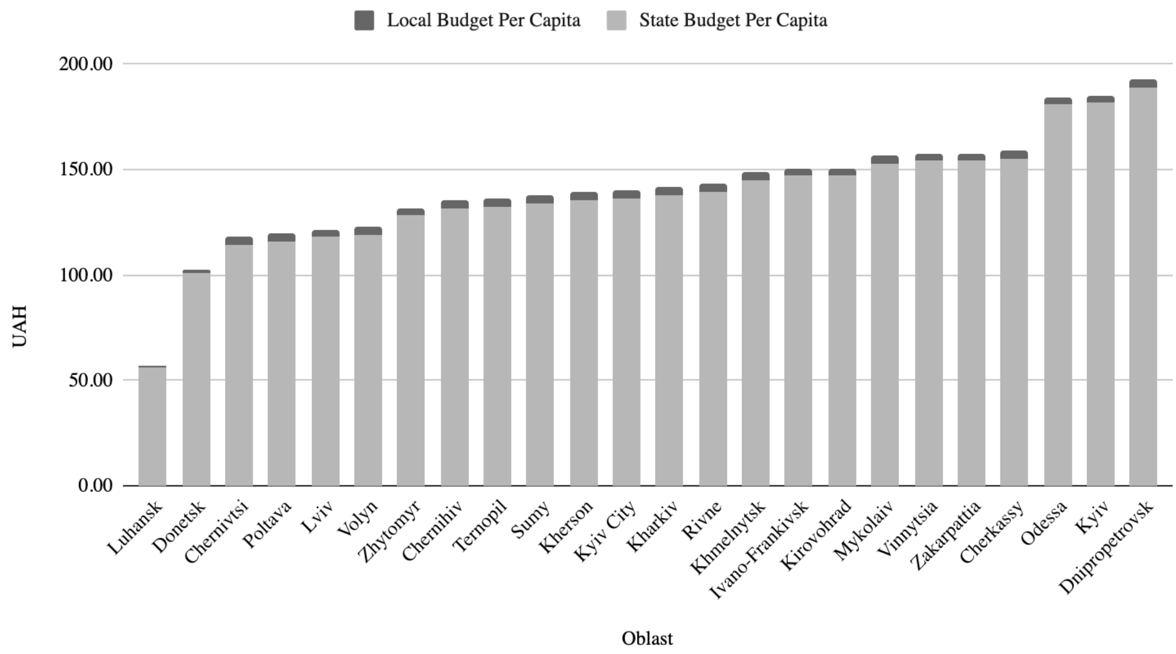
3.3. Emergency Medical Services Financing

EMS in Ukraine is publicly owned, and all care is provided at no cost to the patient [1]. Prior to April 1st, 2020 the EMS was mainly financed through the medical subvention, which was allocated from the central budget. Within the health finance reform, EMS care is now covered by state medical guarantees. Therefore, starting from April 1st, 2020 the NHSU has started signing direct contracts with the oblast's EMS Centers and will pay for their services using the global budget and precipitation rates [6] (Figure 7). Additionally, a portion of the EMS can still be funded through the oblast and/or local government budgets.

According to the National Treasury of Ukraine, in 2018, Ukraine`s spending on healthcare accounted for UAH 115,851,957,855, or 9.27 percent of the total consolidated budget. Out of which, 5.2 percent (UAH 6,031,837,690) was allocated for

EMS care. The regional budget contributed 2.3 percent (UAH 5,894,382,545) to the total spendings on EMS [98]. This amount equates to an average spending of around UAH 142,31 per resident (equivalent to EUR 5.13). Figure 7 shows the per capita spendings by oblast in 2018. The EMS finance varied notably between each oblast (CV 20.72), from only UAH 55.81 in Luhansk to UAH 188.90 in Dnipropetrovsk.

Figure 3.5. Per capita spendings on EMS by oblast in 2018

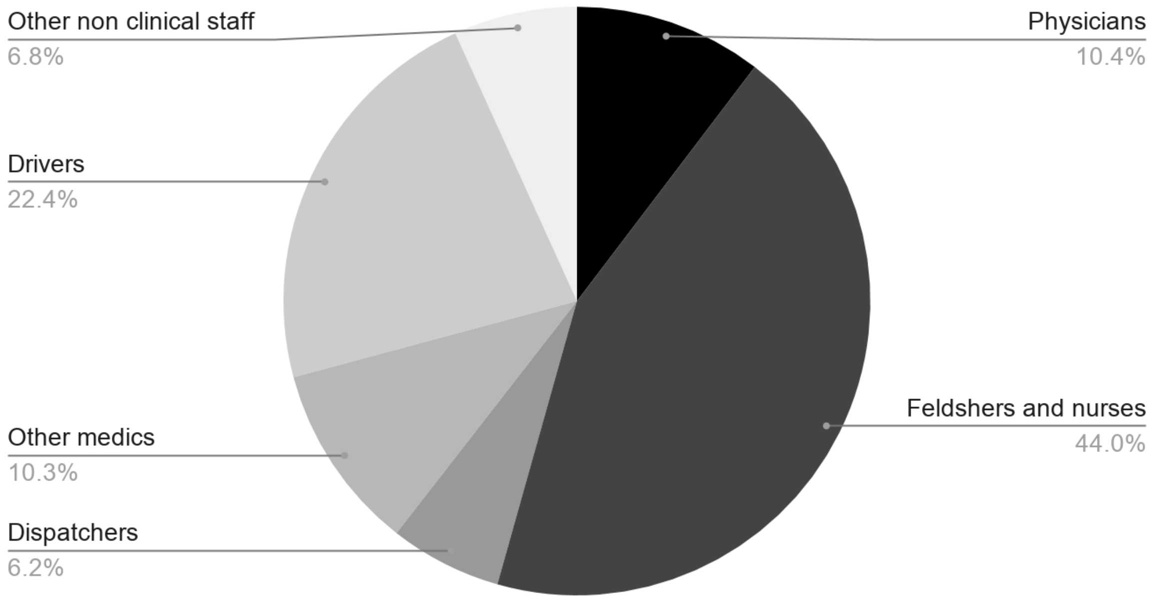


Adapted from: [98]

3.4. Emergency Medical Services Workforce

In Ukraine, a total of 42,373 people works in EMS, or more specifically there is a density of approximately 10.11 EMS workers per 10,000 population. Approximately 10 percent of the EMS workers are physicians, while the remainder are feldshers, nurses, and other clinical and non-clinical personnel (Figure 8). Physicians that work in the Ukrainian EMS system usually have a specialisation in medicine during emergency conditions, this education takes approximately three years of postgraduate training to obtain. While the education of a feldsher requires undergoing a three year technical diploma program instead of matriculation to high school [10].

Figure 3.6. EMS personnel in Ukraine by profession, in 2019

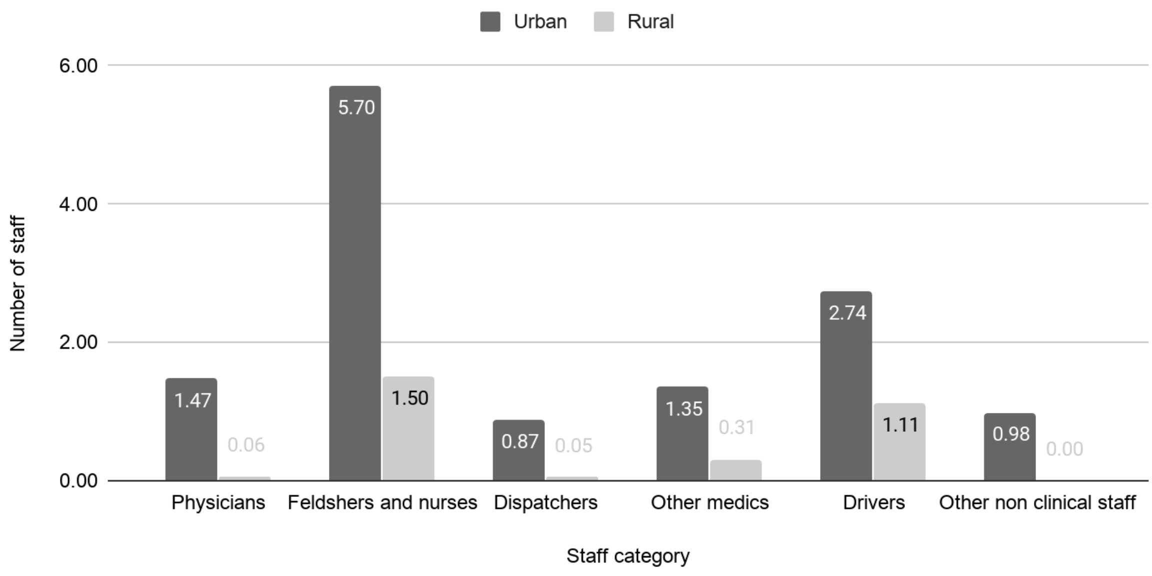


Adapted from: [97]

A concern with regards to ensuring that there are sufficient EMS workers in Ukraine is the distribution of the workers. The distribution is heavily skewed to urban areas, as shown in Figure 9. The staff density in urban areas is about 5 times the density in rural areas, with approximately 14.45 EMS workers per 10,000 population in urban areas, and 3.03 EMS workers per 10,000 in rural areas. Furthermore, almost all of the doctors are located in urban areas, with 1.47 per 10,000 population located in urban areas and 0.06 in rural areas.

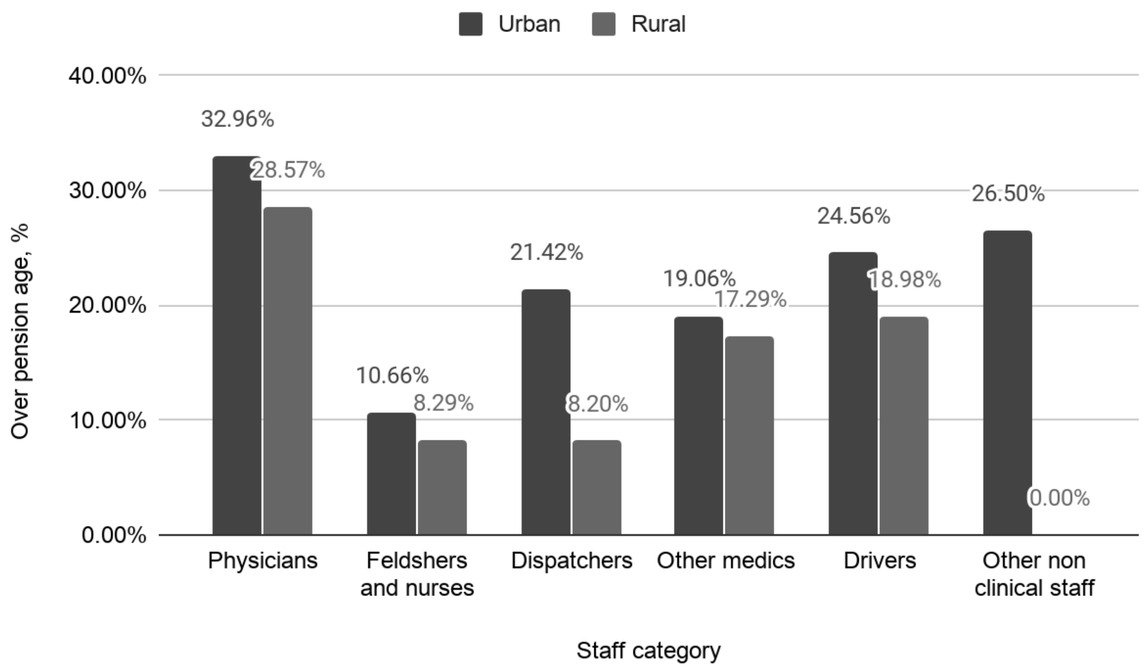
Another important feature of the current workforce is the high number of people working in EMS who are of a pension age or older. As shown in Figure 10, over one in six EMS staff overall are of pension age, although this issue is particularly prevalent amongst doctors employed by the service, with almost one in three doctors overall being of the pension age. The figures are much lower for feldshers and dispatchers, especially in rural areas.

Figure 3.7. Personnel per 10,000 population by type and urban/rural in 2019



Adapted from: [97]

Figure 3.8. Percentage of personnel by profession and urban/rural



Adapted from: [97]

3.5. Emergency Medical Services Information and Communication Technologies

3.5.1. Activation of Emergency Medical Services

EMS in Ukraine are accessible through one unified telephone number, '103'. Although, this number only provides an emergency medical response, without simultaneously alerting the fire services or the police. The caller is connected to the EMS dispatch center in its respectful oblast. The majority of oblasts have one dispatch center, which receives all of the calls and coordinates EMS responses within the oblast. Although, some of the oblasts have several dispatch centres, each responsible for only part of the oblast [10]. Moreover, some oblasts have upgraded their system to computerised dispatch software, while others still use paper based record keeping [10]. The dispatchers who take the call are usually medical professionals, feldshers or nurses. Even in dispatch centers that use computer software, the dispatcher who takes the call usually decides on the priority of the call based on their experience, without the use of any protocols or automated questionnaires.

3.5.2. Collection of Emergency Medical Services Operational Data

The MoH has created a central dispatch data repository on the national level, called 'Central 103' [12]. Its aim is to collect real time operational data on the performance of EMS. This data can be used by the government authorities to better plan for service delivery, conduct benchmarking between regional systems, and suggest improvements. Currently, almost all of the oblasts are functionally connected to the 'Central 103', as this is one of the requirements to receive funding from the NHSU.

3.6. Emergency Medical Services Essential Medicines and Equipment

3.6.1. Emergency Medical Services Fleet

The Ukrainian EMS system uses two types of ambulances: Type B - an emergency ambulance; and Type C - a mobile intensive care unit [6]. The required number of ambulances are calculated based on the population (1 per 10,000 population). However, the actual number of ambulances employed by the EMS in 2019 was 2,947 (0.7 per 10,000 population) [97]. Of them, 92 percent are Type B and the remainder are Type C.

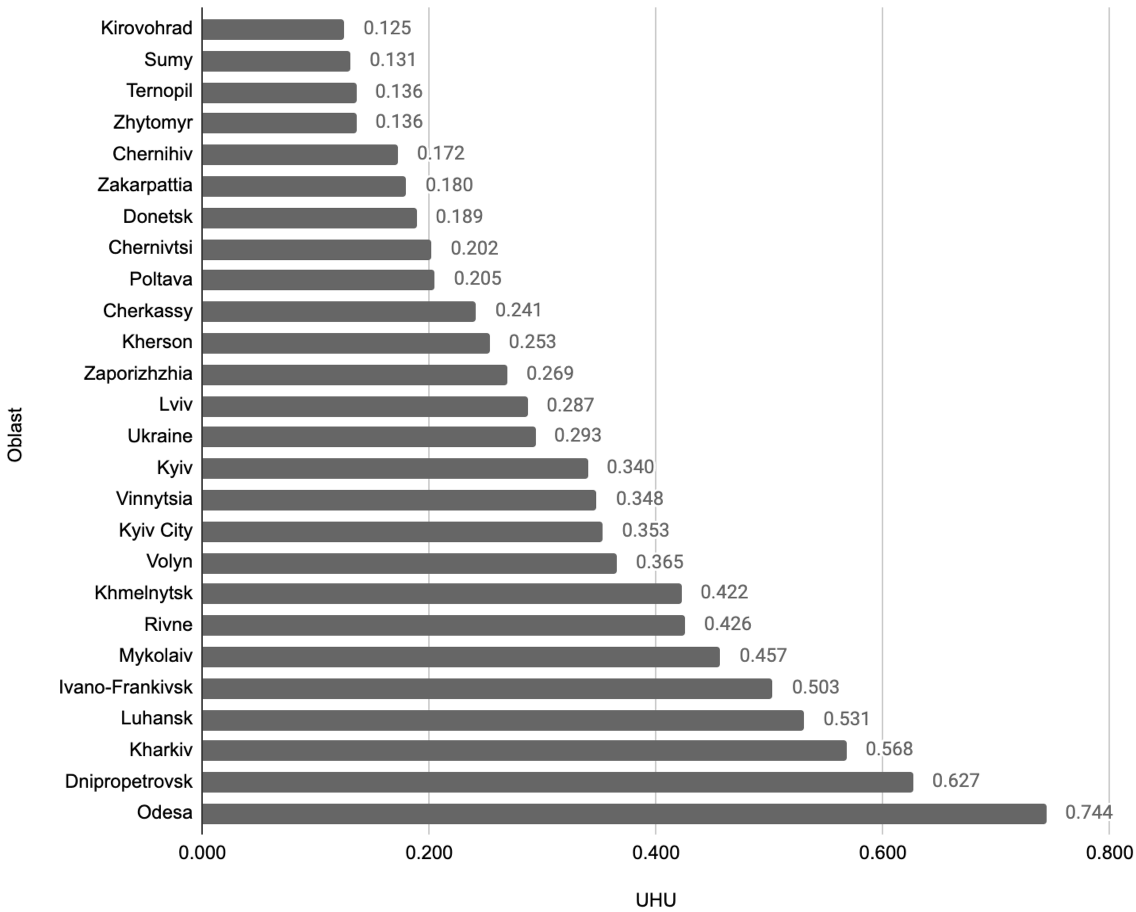
3.6.2. Emergency Medical Services Fleet Utilization

Another area to assess is the productivity of the ambulance crews that are currently in operation. The basic measure of productivity is the 'Unit Hour Utilization' (UHU), which represents the average number of calls attended by a brigade in a 24-hour period [99]. An UHU of 0.45 or more is considered optimal utilization, while a value of 0.35–0.45 is above average, 0.25–0.35 is average, 0.15–0.25 is below average, and under 0.15 is poor utilization.

Figure 11 shows that the UHU by region and for Ukraine as a whole. The calculations indicate that on average, in Ukraine, the UHU is average (0.293), with most of the regions falling within the average range. The utilisation of ambulances in different oblasts differs significantly (CV 0.51). Four oblasts (Kirovohrad, Sumy, Ternopil and Zhytomyr) show poor utilization, while six oblasts show optimal utilization (Mykolaiv, Ivano-Frankivsk, Luhansk, Kharkiv, Dnipropetrovsk, and Odesa).

In conclusion, the Ukrainian EMS system is well functioning, however, several gaps and inequalities were discovered in the health system building blocks analysis. The next chapter will present more precise findings on how system components affect patients' outcomes.

Figure 3.9. UHU by oblasts of Ukraine

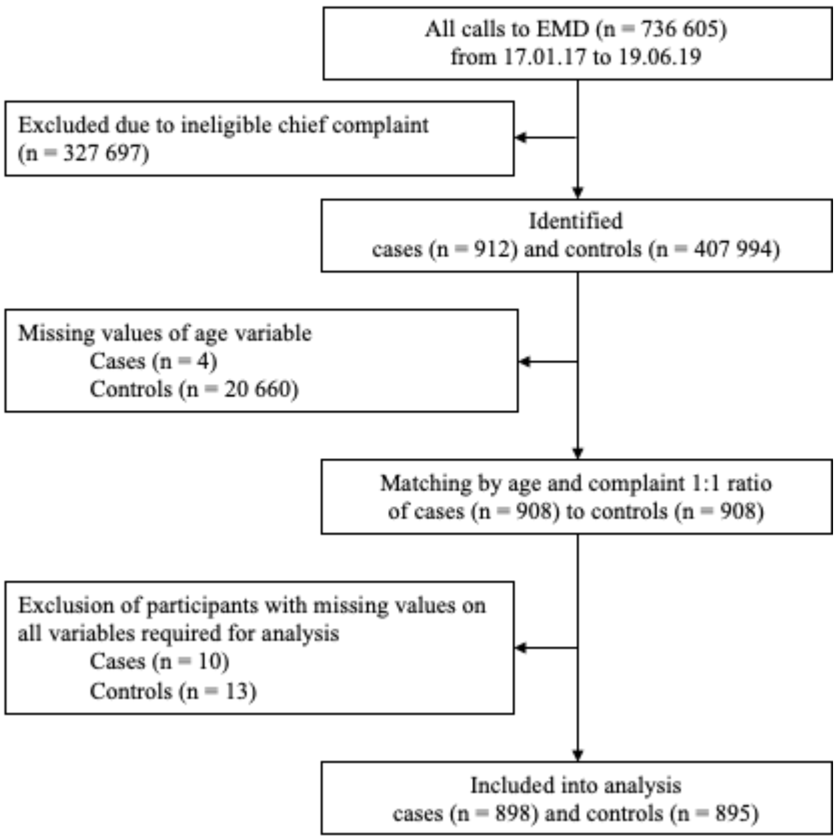


CHAPTER 4. RESULTS OF CASE-CONTROL STUDY

4.1. Study participants

From January 17th, 2017 to June 19th, 2019 the Vinnytsia oblast EMS received a total of 736 605 calls to their regional emergency medical dispatch center. After screening all calls for eligibility of chief complaint, a total of 408 906 (55.5%) calls were included in the study (Figure 12). All calls that are coded as "death examination" and "interfacility transport" by the dispatcher are not considered emergencies, and therefore were not in the scope of the study. The patients with chief complaints that were coded as 'patient sick' and 'unconsciousness' were also not included in the study, because the actual patient's medical condition cannot be identified from such a coding.

Figure 4.1. Inclusion of participants

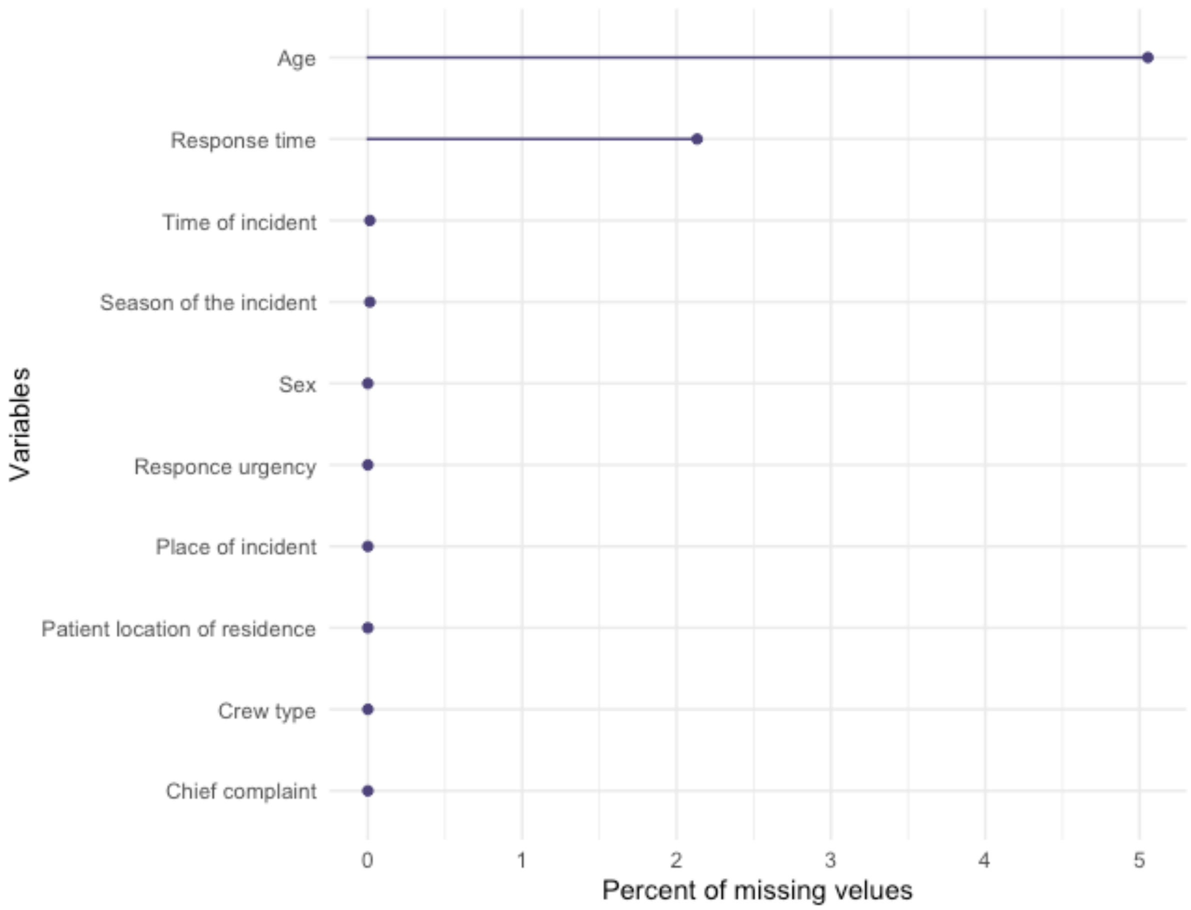


Among all calls included in the study, 912 (0.22%) cases and 407 994 (99.78%) controls were identified. Before proceeding to the matching of cases to controls, confounders were assessed for completeness of data. Figure 13 shows the percent of missing values per each variable that were included in the analysis at this stage.

The matching variables for missing values excluded were four (0.44%) cases and 20 660 (5.01%) controls, for missing age. No missing values for chief complaints were found at this stage.

Next, a matching of 908 cases to controls was performed, by age and complaint to minimize confounding, using a one to one ratio. When there was more than one control per case, one was chosen at random. Upon the completion of matching cases to controls, the matched pairs were examined for completeness of variables required for further statistical analysis. At this stage, 10 cases and 13 controls were excluded for having missing values that were required for further analysis.

Figure 4.2. Percent of missing values on variables included in to the analysis



4.2. Descriptive and outcome data

After the matching was performed, a total of 898 cases and 895 controls were included in the analysis (Table 1). First, the covariates were assessed on which cases were matched to controls to confirm that the matching was performed correctly. The average age of cases (63.98 years, SD 16.54) was not statistically different (p = 0.687) from the controls (63.66, SD 16.54). Cardiac complaints were the most common for patients that were included in the study, 336 (37.4%) of cases, and 334 (37.3%) controls. Followed by patients with difficulty breathing and strokes. The chief complaints of cases were not different (p = 1.000) from controls. Such results confirmed that the exact matching based on age and complaint was performed correctly.

Table 4.1. Characteristic of matched cases and controls

	Controls (n = 895)	**Cases (n = 898)**	**p**	**Test**
Patient age, years (mean (SD))	63.66 (17.01)	63.98 (16.54)	0.687	T-test
Chief complaint (%)			1.000	Chi-Square
Cardiac complaints	334 (37.3)	336 (37.4)		
Acute poisoning	14 (1.6)	14 (1.6)		
Diabetic complaints	25 (2.8)	26 (2.9)		
Acute allergy	4 (0.4)	4 (0.4)		
Bleeding	32 (3.6)	32 (3.6)		
Difficulty breathing	229 (25.6)	227 (25.3)		
Pain syndrome	69 (7.7)	70 (7.8)		
Stroke	79 (8.8)	79 (8.8)		
Seizures	42 (4.7)	42 (4.7)		
Trauma	67 (7.5)	68 (7.6)		
Patient sex (%) *			<0.001	Chi-Square
Male	387 (43.2)	534 (59.5)		
Female	507 (56.6)	362 (40.3)		
Unknown**	1 (0.1)	2 (0.2)		
Season of the incident (%)			0.073	Chi-Square
Fall	193 (21.6)	183 (20.4)		
Spring	283 (31.6)	317 (35.3)		
Summer	169 (18.9)	189 (21.0)		
Winter	250 (27.9)	209 (23.3)		
Time of incident (%)			0.017	Chi-Square

	Controls (n = 895)	Cases (n = 898)	p	Test
00:00 - 05:00	92 (10.3)	88 (9.8)		
05:00 - 11:00	206 (23.0)	236 (26.3)		
11:00 - 16:00	218 (24.4)	250 (27.8)		
16:00 - 19:00	147 (16.4)	148 (16.5)		
19:00 - 24:00	232 (25.9)	176 (19.6)		
Crew type (%)			0.068	Chi-Square
Physician lead	490 (54.7)	489 (54.5)		
Feldsher lead	55 (6.1)	36 (4.0)		
Other	349 (39.0)	368 (41.0)		
Unknown	1 (0.1)	5 (0.6)		
Response urgency (%) *			<0.001	Chi-Square
Urgent	667 (74.5)	758 (84.4)		
Non-urgent	36 (4.0)	13 (1.4)		
No priority	192 (21.5)	127 (14.1)		
Patient residence (%)			0.265	Chi-Square
Urban	572 (63.9)	575 (64.0)		
Rural	282 (31.5)	323 (36.0)		
Unknown	41 (4.6)	0 (0.0)		
Place of the incident (%) *			<0.001	Chi-Square
HCF	19 (2.1)	21 (2.3)		
Home	765 (85.5)	740 (82.4)		
Other	13 (1.5)	27 (3.0)		
Public place	44 (4.9)	102 (11.4)		
Unknown **	42 (4.7)	0 (0.0)		
Work ***	12 (1.3)	8 (0.9)		
Response time, mins (median [IQR]) *	15.48 [11.16, 24.57]	19.02 [13.13, 36.53]	<0.001	Mann-Whitney U

* Included into the model

** Removed before entering to the model

*** Combined with "Other"

Upon examining matched confounders, the difference between exposure factors in the two groups was measured. The data showed that the proportion of males and females was significantly different (p = <0.001) between the study groups. The majority of cases were found to be male (n = 534, 59.5%), as opposed to the controls, most of which were females (n = 507, 56.6%).

Every third emergency in the study population happened during the spring. Compared to the total, 317 (35.3%) cases and 283 (31.6%) controls requiring emergency care occurred during March, April or May. The number of emergency calls during the winter was the second highest, with 209 (23.3%) cases and 250 (27.9%) controls. There was the lowest number of calls in the summer, with only 189 (21.0%) cases and 169

(18.9%) controls. There was no significant difference (p = 0.073) in the distribution of calls to the EMS between the cases and controls during the different seasons.

The time of the call was the next exposure factor assessed. The biggest proportion of calls in the cases (n = 250, 27.8%) was received by the dispatcher during the period of 11:00 to 16:00 hours. In contrast, for the controls the most frequently (n = 232, 25.9%) received calls were during the period of 19:00 to 24:00 hours. The lowest number of calls was during the period of 00:00 to 05:00, in both groups. As there were 88 (9.8%) calls for amongst the cases and 92 (10.3%) calls amongst the controls. No significant variation (p = 0.017) was found between the two study groups, with regards to the time of inquiring for EMS care.

The next exposure factor that we assessed was the type of crew that responded to the incident. Physician lead EMS crews most frequently responded to the incidents of both cases and controls, with 489 (54.5%) responses and 490 (54.7%) responses, respectively. Feldsher lead crews responded only to 36 (4.0%) of the cases and 55 (6.1%) of the controls. Other types of crews, such as specialized units staffed with cardiac or psychologists specialists, responded to 368 (41.0%) cases and 349 (39.0%) controls. Five (0.6%) EMS responses to cases and one (0.1%) control did not have information on the type of crew that responded to the incident. There are no significant differences (p = 0.068) in the exposure factors between the two study groups.

Cases in the study showed to have a higher number of urgent calls than the controls. There were 758 (84.4%) cases coded as urgent by dispatchers, and 667 (74.5%) from the controls. This coincides with the number of non-urgent calls, they were more prevalent among controls (n = 36, 4.0%) than cases (n = 13, 1.4%). One hundred twenty-seven (14.1%) of cases and 192 (21.5%) of controls were not assigned any priority by the EMS dispatch triage system. The difference in the priority of calls was statistically significant (p = <0.001) between two study groups.

The majority of patients in both groups were living in urban regions, 575 (64.0%) of the cases and 572 (63.9%) of the controls. Patients living in rural settings were equally represented in the two groups, 323 (36.0%) of the cases and 282 (31.5%) of the controls. Forty-one (4.6%) of the controls did not have information registered with regards to the patient's residence. All cases had complete information on this variable. This exposure factor did not have a significant (p = 0.265) difference between cases and controls.

The exact place of the incident is another exposure factor included in the analysis. Both cases (n = 740, 82.4%) and controls (n = 765, 85.5%) most frequently sustained emergencies at home. It was observed that the EMS was called from a public place twice more frequently amongst the cases (n = 44, 4.9%) than that of the controls (n = 102, 11.4%). This difference also found to be statistically significant (p = <0.001). None of the cases had missing values on this variable, in contrast to controls that had 42 (4.7%) locations unknown.

Finally, the EMS response time was examined as another exposure factor. Overall, EMS responded 3.54 minutes faster to controls than to cases. EMS reached cases at a median 19.02 minutes from the time of the call (IQR[13.13, 36.53]). Compared to controls, which arrived at 15.48 minutes from the time of the call (IQR[11.16, 24.57]). The difference in the response time is statistically significant (p = <0.001).

4.3. Crude and Adjusted Logistic Regression Models

All exposure factors that had a possible association with the outcome were entered into the binary logistic regression model, to determine the magnitude of the association, measured in odds ratio (OR). All small strata (n = >2) of factors included in the model were removed to improve its statistical power. Therefore, participants with unknown sex and unknown place of incident were removed. As only eight cases experienced an emergency at work, the stratum was combined with the "other" place of incident. All factors were recorded into dummy variables. The output of the unadjusted binary logistic regression, assessing each exposure factor and confounder individually, is presented in Table 2.

Table 4.2. Odds ratio and 95 percent confidence intervals for risk of death during prehospital care

		95% CI		
	OR	**Lower**	**Upper**	**p**
Patient age, years (mean (SD))	0.999	0.993	1.004	0.637
Chief complaint (%)				
Heart complaints	0.979	0.673	1.426	0.914
Acute poisoning	0.926	0.410	2.096	0.854
Diabetic complaints	0.964	0.504	1.841	0.910
Acute allergy	0.926	0.222	3.862	0.916
Bleeding	0.869	0.474	1.590	0.648
Difficulty breathing	0.969	0.656	1.431	0.875
Pain syndrome	0.969	0.598	1.571	0.899
Stroke	0.976	0.612	1.555	0.918
Seizures	0.949	0.548	1.645	0.852
Trauma (reference)				
Patient sex (%)				
Male *	1.909	1.578	2.309	<0.001
Female (reference)				
Response urgency (%)				
Urgent *	1.566	1.215	2.019	<0.001
Non-urgent	0.549	0.277	1.089	0.086
No priority (reference)				
Place of the incident (%)				
HCF	1.149	.613	2.155	0.665
Public place *	2.417	1.667	3.505	<0.001
Other	1.455	.862	2.455	0.160
Home (reference)				
Response time, mins (median [IQR]) **	0.982	0.977	0.987	<0.001

* significant risk factor

** significant protective factor

HCF - health care facility

The ORs in the above table indicate the magnitude of the risk of dying from a particular exposure. Odds ratios of confounding age and chief complaint were found not to be statistically significant. This confirms that confounding was correctly addressed through matching. The study also found that males in the study are almost twice as likely to die during prehospital care, compared to females. They had an OR of 1.909 (95% CI 1.578 - 2.309), which was statistically significant (p = <0.001).

Calls that were categorized by the dispatch us urgent were found to be at a greater risk of dying during the provision of prehospital care when compared to cases that were not categorized. The OR of urgent calls was 1.566 (95% CI 1.215 - 2.019) and statistically significant (p = <0.001). Calls that were categorized as non-urgent appeared to be a protective factor (OR 0.549), however, the confidence interval from 0.277 to 1.089 and a p-value of 0.086 indicate that the protectiveness is not statistically significant.

Taking into account all the places where patients had an incident, those that occurred in a public place are the most at risk of dying during prehospital care. Patients that sustained an emergency in a public place were almost 2.5 times more likely to die during the prehospital treatment phase (OR 2.417; 95 % CI 1.667 - 3.505), this association was significant (p = <0.001). Having an emergency take place at a health care facility (OR 1.149; 95 % CI 0.613 - 2.155; p = 0.665) and in a place coded as "other" (OR 1.455; 95 % CI 0.862 - 2.455; p = 0.160) also increased the risk of death, compared to having the emergency occur at home, although not significantly.

The study found that the response time is a significant protective factor for investigated outcomes. With every minute lost from the response time of the EMS, the chances of death decrease by almost two percent (OR 0.982; 95 % CI 0.977 - 0.987), this association is significant (p = <0.001).

Table 3 presents the results of the adjusted binary logistic regression, aimed at measuring the magnitude of the association between exposure and time. Adjustment was made for the patient's age, chief complaint and all exposure factors, to minimize their confounding.

Upon adjustment, the patient's sex (p = <0.001) and the place of incident (p = <0.001) remained significant risk factors for death during prehospital care. Males are almost twice (AOR 2.063; CI 1.672 - 2.546) as likely to die during prehospital care than females. Patients that suffered from an emergency in a public place had an AOR of 2.658 (CI 1.661 - 4.254), compared to patients that had an emergency at their home.

From the same model, it can also be seen that response time remained a significant protective factor (p = <0.001). With every minute decrease in the response, the risk of dying during the prehospital treatment stage decreased by almost two percent (AOR 0.981; CI 0.976 - 0.986). Although, the urgency of response was no longer significant after the adjustment, changing from p = <0.001 to p = 0.006.

Table 4.3. Adjusted odds ratios and 95 percent confidence intervals for risk of death during prehospital care

		95 % CI		
	AOR	**Lower**	**Upper**	**p**
Patient age, years *	0.990	0.983	0.997	0.004
Chief complaint				
Heart complaints	1.431	0.881	2.325	0.148
Acute poisoning	1.247	0.507	3.065	0.631
Diabetic complaints	1.830	0.883	3.793	0.104
Acute allergy	0.792	0.144	4.337	0.788
Bleeding	1.330	0.675	2.623	0.410
Difficulty breathing	1.544	0.943	2.530	0.084
Pain syndrome	1.782	1.011	3.141	0.046
Stroke	1.160	0.652	2.062	0.614
Seizures	1.211	0.664	2.208	0.532
Trauma (reference)				
Patient sex *				
Male	2.063	1.672	2.546	<0.001
Female (reference)				
Response urgency				
Urgent	1.445	1.110	1.881	0.006
Non-urgent	0.528	0.262	1.063	0.074
No priority (reference)				
Place of the incident				
HCF	0.998	0.512	1.944	0.994
Public place *	2.658	1.661	4.254	<0.001
Other	1.119	0.629	1.989	0.703
Home (reference)				
Response time, mins*	0.981	0.976	0.986	<0.001

* statistically significant

The chief complaints that were used for matching remained as not significant exposure factors, with the strongest significance of the pain syndrome with a p-value of p = 0.046 and weakest p-value of p = 0.788 for the acute allergy. The patients' difference in age increased in its significance from a p-value of p = 0.637 before adjustment, to p = 0.004 after adjustment, with an AOR of 0.990 (CI 0.983 - 0.997). This indicates that with every decrease of a year in the patient's age, the chances of dying during prehospital care decreased by one percent.

In summary, the AOR showed that sex and place of incident are significant risk factors for death during prehospital treatment. While age and response time are significant protective factors.

4.4. Additional analysis of missing values

The final area to examine is to check that the selected controls still represent the source population, given that a substantial amount of them were removed due to missing values. Therefore, frequencies of all exposure factors of selected controls were compared to the source population. The comparison is presented in Table 4.

It can be observed that the source population was 11 years younger than the selected controls (p = <0.001). The source population's median age is 56 years old (IQR 32.00, 72.00) and that of the selected controls is a median age of 67 years old (IQR 55.00, 77.00). Similarly, to the age, the chief complaints were also significantly different between the source population and selected controls (p = <0.001). The controls that were selected for analysis had presumably more dangerous chief complaints than the source population. For example, selected controls had 11.4 percent more patients with heart complaints and 15 percent more patients with difficulty breathing than the source population. This can be explained by the fact that the chief complaint was used for matching.

A significant difference (p = <0.001) was also found in the patient's location of residence and the place of incident. Generally, the source population had more 'unknown' records in both factors. This can be explained by the fact that the selected cases were more severe than the source population, due to the matching, which is why the ambulance crew paid more attention to completing the medical records of the more severe calls.

Table 1.4. Controls used in the model compared with the source population

	Population (n = 386 486)	Controls (n = 848)	p	Test
Patient age, years (median [IQR]) *	56.00 [32.00, 72.00]	67.00 [55.00, 77.00]	<0.001	Mann-Whitney U
Chief complaint (%) *			<0.001	Chi-Square
Heart complaints	98768 (25.6)	314 (37.0)		
Acute poisoning	13969 (3.6)	13 (1.5)		
Diabetic complaints	5337 (1.4)	25 (2.9)		
Neonatal emergency / delivery	5408 (1.4)	0 (0.0)		
Acute allergy	7265 (1.9)	4 (0.5)		
Psychological disorders	9780 (2.5)	0 (0.0)		
Bleeding	15694 (4.1)	32 (3.8)		
Difficulty breathing	40801 (10.6)	217 (25.6)		
Pain syndrome	83746 (21.7)	65 (7.7)		
Stroke	28135 (7.3)	75 (8.8)		
Seizures	13917 (3.6)	40 (4.7)		
Trauma	61713 (16.0)	63 (7.4)		
Burns	1953 (0.5)	0 (0.0)		
Patient sex (%)			0.247	Chi-Square
Male	173452 (44.9)	368 (43.4)		
Female	212153 (54.9)	480 (56.6)		
Unknown	881 (0.2)	0 (0.0)		
Season of the incident (%)			0.316	Chi-Square
Fall	82802 (21.4)	185 (21.8)		
Spring	116212 (30.1)	275 (32.4)		
Summer	82996 (21.5)	164 (19.3)		
Winter	104429 (27.0)	224 (26.4)		
Time of incident (%)			0.148	Chi-Square
00:00 - 05:00	49042 (12.7)	87 (10.3)		
05:00 - 11:00	86562 (22.4)	197 (23.2)		
11:00 - 16:00	89507 (23.2)	212 (25.0)		
16:00 - 19:00	58468 (15.1)	138 (16.3)		
19:00 - 24:00	102860 (26.6)	214 (25.2)		
Crew type (%)			0.038	Chi-Square
Physician lead	198506 (51.4)	466 (55.0)		
Feldsher lead	25832 (6.7)	49 (5.8)		
Other	160188 (41.4)	333 (39.3)		
Unknown	1960 (0.5)	0 (0.0)		
Response urgency (%)			0.321	Chi-Square
Urgent	288962 (74.8)	649 (76.5)		
Non-urgent	13373 (3.5)	32 (3.8)		
No priority	84151 (21.8)	167 (19.7)		
Patient residence (%) *			<0.001	Chi-Square
Urban	241224 (62.4)	567 (66.9)		
Rural	121843 (31.5)	281 (33.1)		
International	857 (0.2)	0 (0.0)		
Unknown	22562 (5.8)	0 (0.0)		
Place of the incident (%) *			<0.001	Chi-Square
HCF	8815 (2.3)	19 (2.2)		
Home	305235 (79.0)	761 (89.7)		
Other	7465 (1.9)	13 (1.5)		
Public place	35274 (9.1)	43 (5.1)		
Unknown	25431 (6.6)	0 (0.0)		
Work	4266 (1.1)	12 (1.4)		
Response time, mins (median [IQR])	15.57 [11.30, 25.32]	15.45 [11.11, 24.21]	0.340	Mann-Whitney U

* statistically significant factor

In summary, matching of cases to controls was done correctly; therefore, confounding from the patient's age and the complaint was controlled on this stage. It was determined that the following exposure factors were significantly different ($p = <0.005$) between the two study groups and may be associated with the outcome: patient's sex, the urgency of the response, place of the incident and response time. Thus, all exposures that were found to be statistically significant were included in the binary logistic regression model, to determine the magnitude of the association.

CHAPTER 5. DISCUSSION

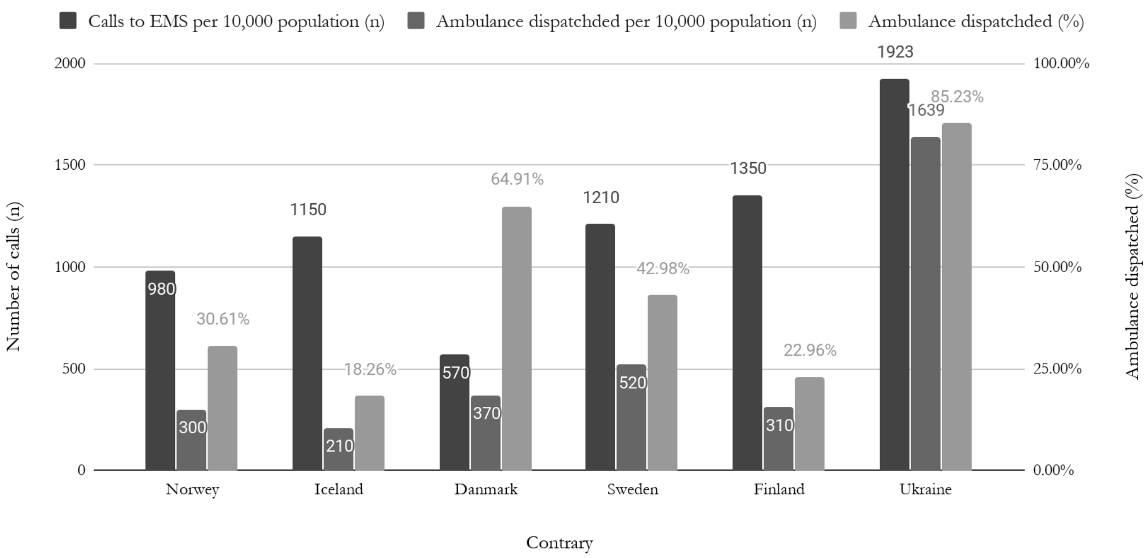
5.1. EMS System Building Blocks Key Findings and Interpretation

By analyzing the Ukrainian EMS systems with the use of the World Health Organization's health system building blocks approach, the study discovered several challenges that the system is facing across several areas of the healthcare system. The identified challenges include the irrational use of limited resources, inequalities in state funding of oblast EMS centers, variations in the utilization of fleets, and skewed distribution of workforce between urban and rural settings. This section discusses the causes and consequences of these challenges, and proposes solutions based on international best practices in EMS systems organisation.

5.1.1. Irrational Use of Limited EMS Resources

One of the most acute issues that was found by the study is the irrational use of limited EMS resources. First, the number of calls that the Ukrainian EMS receives each year is substantially larger than in other countries. In 2019, the Ukrainian EMS received 1,923 calls per 10,000 population, compared to only 370 and 520 calls per 100,000 population, respectively in Denmark and Sweden (Figure 14) [100]. Moreover, despite such a drastic amount of calls, the Ukrainian EMS does little to filter the calls that actually require an ambulance response from those calls that do not. The percentage of ambulance responses per number of calls received by the Ukrainian EMS is 85.2 percent (1,639 per 10,000 population), while in other European EMS systems this figure ranges from 18.26 percent in Iceland to 64.91 percent in Denmark. The high demand for using EMS by the Ukrainian population, combined with the inability of the system to filter genuine emergencies, results in an EMS system that is significantly overwhelmed.

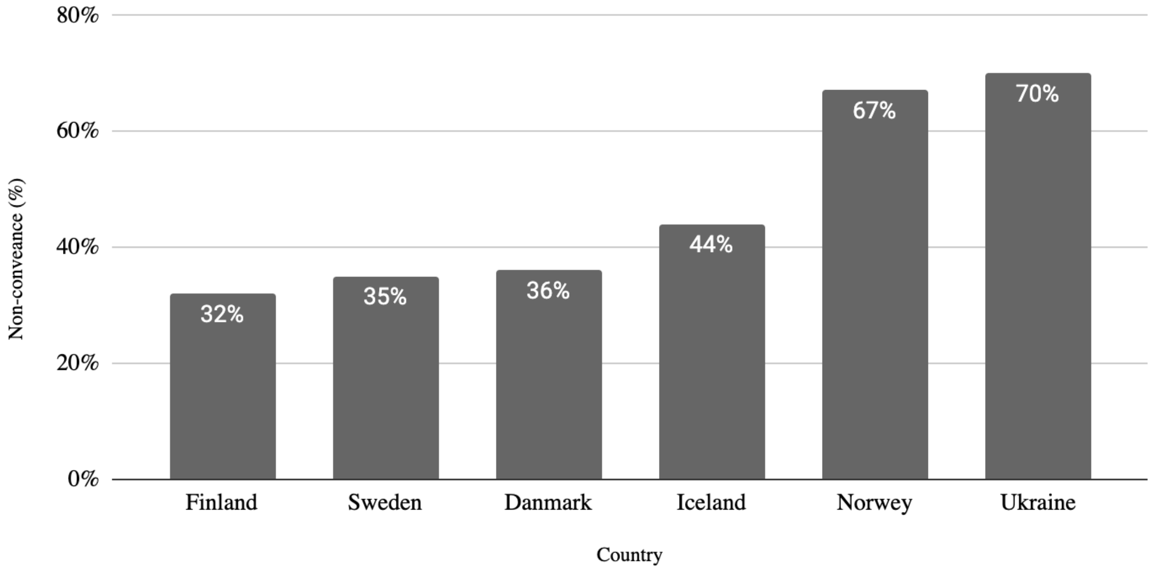
Figure 5.1. Number of calls and ambulance responses per 10,000 population in Ukraine compared to countries



Adapted from: [97,100]

The statement above is confirmed by the fact that the majority of incidents to which the Ukrainian EMS dispatches ambulances does not actually require the response of an emergency ambulance. As the results of this study found that in 2019, only 30 percent of EMS responses resulted in patients being transported to the hospital, which would be the primary case for the use of Type B or C ambulances being justified [101]. This means that there is a high chance that in the remaining 70 percent of responses, the care could have been provided by alternative means. Alternative means which are used in other countries include, telephone consultations, responses of medical professionals on non-emergency vehicles or Type A ambulances, referrals of patients to the emergency department, walk-in clinics or consultations with primary care physicians. Providing alternative responses is standard practice across many well established systems [102]. Especially as the non-conveyance rate in Ukraine is almost three times higher than in Finland, Sweden and Denmark, although it is only three percent higher than in Norway (Figure 15). Furthermore, the costs related to an ambulance response is much higher than the provision of alternative responses, such as consultations by phone or the referral of the patients to HCFs. Resulting in the already limited health resources in Ukraine being used irrationally.

Figure 5.2. Ambulance non-convince rate in Ukraine compared to other countries



Adapted from: [97,100]

Furthermore, such dilution of already limited resources does not allow the EMS to provide timely care to those patients who are actually sick or injured. Especially as the Ukrainian EMS system is already struggling to achieve response time targets. In Ukraine, although the requirements for EMS response times to urgent calls are in line with other European countries (10 minute in urban areas and 20 minutes in rural areas), official government statistics indicate the EMS does not comply with these national standards [103]. Specifically, as noted in the results, compliance to the national response time standards ranges from 36 percent in Vinnytsia oblast to 100 percent in Odesa oblast. For comparison, it should be noted that generally response times in other European countries range from 5 minutes in Germany to 20 minutes in the Czech Republic [104]. Long response times that are caused by an irrational use of resources can negatively influence outcomes of those patients who are acutely sick or injured [56,58].

The irrational use of ambulances can be linked to several potential causes. First, the population of Ukraine may have a low awareness of when to use EMS and when to refer to other health services. To resolve this specific problem, there are many proven interventions aimed at reducing the demand for EMS services, in different countries [102,105,106]. These interventions can and should be utilized in Ukraine to reduce the number of calls to the EMS. Second, the Ukrainian EMS does not use computer-aided call prioritization software to help dispatchers decide on whether an ambulance is needed, and if it is, then how urgently it should arrive. Such software is used by EMS systems globally, and it proved to be much more effective than humans in determining the priorities of calls received by the EMS dispatcher [73]. Implementation of such software can help the Ukrainian EMS to better allocate limited resources to where they are needed. As well as accurately suggest when alternative responses should be used instead of dispatching an EMS ambulance. Third, the high demand for EMS can be explained by a lack of access of the population to other health services, such as to primary care physicians. Several studies found that EMS are often used to cover such gaps in access to other parts of the healthcare system [106,107]. Therefore, by strengthening other health services and making them more accessible to the population, a reduction in the number of calls to the EMS can be achieved. This consequently will improve care for patients in emergency conditions and improve outcomes.

5.1.2. Inequalities in State Funding for the Oblast EMS Centers

By reviewing the EMS finances in Ukraine, the study found significant variations between oblasts. With only a UAH 55.81 per capita in Luhansk to a UAH 188.90 per capita in Dnipropetrovsk, which is over 340 percent more. This is a striking variation between two publicly owned systems within one country. Especially considering the majority of the funding comes from the central budget [98]. For example, similar variations between different ambulance trusts in the United Kingdom account for only about 20 percent [108]. Due to such differences, some oblasts potentially provide significantly lower standards of care than others. Additionally, this may also result in discrepancies in the outcomes between the oblasts. Considering that the provision of emergency care is guaranteed to citizens in all oblasts by law, and it is also included in the state guaranteed package of medical services, the finances between oblast's EMS must be allocated more equality, to allow for provision of the same standard of care across all oblasts.

Although it is difficult to say for certain, it can be speculated that the inequalities in finances between the oblasts may be caused by a poorly organised system of payments for health services. Such differences show that the system is unable to accurately calculate costs for the particular demand of health services. However, in the context of the overall health finance reforms in Ukraine, EMS care will be financed by the NHSU, such a change will potentially resolve this challenge. Chiefly because the NHSU uses a model for EMS payments that aims to distribute finances more equally between the oblasts. However, the effectiveness of the new model will require further evaluation, as more data will become available.

5.1.3. Variation in the Utilization of EMS Fleet

The analysis conducted in the study showed varying results, as from the outside the information shows that many aspects of the Ukrainian EMS in terms of ambulance use is in line with European standards. For example, similarly to other European countries, Ukraine primarily utilizes Type B ambulances, having 92 percent of all its ambulances as such. Furthermore, the overall density of ambulances in Ukraine is 0.7 ambulances per 10,000 population, which is relatively high in comparison to other European Countries, where density of ambulances ranges from 0.45 in the Netherlands to 0.74 in Hungary [104]. But by analysing the EMS fleet, this study discovered that ambulances were underused in some regions, while other regions require more vehicles to meet the demand. Therefore, despite the sufficient numbers of ambulances on a national level, their utilisation varies drastically by oblast (CV 0.51). More precisely, the study found that Kirovohrad, Sumy, Ternopil, and Zhytomyr oblasts have a poor utilisation of available ambulances. While other oblasts have above optimal utilisation and may require more ambulances to meet their growing demand for services, such as in Mykolaiv, Ivano-Frankivsk, Luhansk, Kharkiv, Dnipropetrovsk, and Odesa oblasts. Such a disproportionate allocation of ambulances suggests that while one oblast may not be able to provide timely response due to their shortage of ambulances, another oblast has more ambulances than it needs.

Such disproportionate distribution of ambulances between oblasts suggests that either there are problems with the ambulance distribution standards or there is a lack of adherence to these standards, consequently they may need to be revised. Currently, the standards only consider the population living in the given oblast for estimating the required number of ambulances. However, this method for calculation does not account for the demand for services that may differ due to a variety of local and geographical factors. For example, in Odesa oblast the demand for EMS increases significantly during the summer season, as it is a popular summer holiday destination in Ukraine and there significantly more people. In recent years, several methods for estimating the required amount of ambulances needed, based on the actual demand for services have been developed [109]. Implementing these methods to determine ambulance distribution standards will allow the Ukrainian EMS to better allocate resources that are already available within the system. As well as ensuring an equal standard of care across all regions of Ukraine.

5.1.4. Skewed Distribution of EMS Workforce

The study focused on evaluating the health system building blocks also discovered that the majority of EMS staff is distributed disproportionately between urban and rural settings. As five times more EMS staff work in cities than in rural areas. Especially EMS physicians, they are over 24 times more frequently employed in cities than in rural areas. Shortages of EMS workforce in rural areas can also lead to poorer access and quality of services provided to the population living in those areas.

Such a situation arises due to the low motivation of staff to work in rural areas, this may be caused by poor working conditions, lower compensation, or other factors [10,110]. The findings of this study clearly indicate the need to review the current EMS workforce strategy, to consider how to attract more workforce to work in rural settings, as a sufficient amount of health workforce is crucial for providing adequate care to the population of Ukraine.

5.2. Case-Controls Key Findings and Interpretations

By conducting the case-control study of risk factors associated with the mortality during prehospital treatment, several risk factors were identified as statistically significant. They include prolonged response times, emergencies located in public places, and classification of males and older patients. No difference in patient outcomes was detected with regards to the time of day and the season of the year. This section discusses the causes and consequences of identified risk factors, and proposes solutions aimed at reducing mortality during prehospital care.

5.2.1. Readiness of Emergency Medical Services to Respond

The Vinnytsia oblast EMS system provides equal quality services 24 hours a day, all year round. The case-control study found that the risk of dying during prehospital care does not differ by the time of the day, nor by the season of the year. The exposure factors did not significantly differ between the two study groups, with p-value equal to 0.017 when comparing the time of the day between the cases and control, and p-value equal to 0.073 when comparing the season of the year, although, the time of the day would be different if significance level were set to a higher threshold. Therefore, it can be concluded that the emergency services are not interrupted by weather conditions during the winter and have sufficient resources during both the day and night to meet the demand of care needed.

The work of the EMS in Vinnytsia on maintaining equal quality services by season and time of the day should be acknowledged. Especially as other studies found that the demand for services changes significantly due to these factors. For example, a study done in a large metropolitan EMS system in Melbourne, Australia found a significant variation in the number of cases by the time of the day [64]. Furthermore, a study by Shiga University of Medical Science Hospital in Japan found that the demand for emergency services rose dramatically during the summer [58]. This finding suggests that the Vinnytsia EMS maintains equal quality of service despite variation in demand. However, this finding does not say anything about the overall quality of the service.

5.2.2. Timely Response Improves Outcomes

The results of the study show that the EMS response time is a significant protective factor for mortality during prehospital care in Vinnytsia oblast. Accordingly, it can be said that the response time of the Vinnytsia Oblast EMS Center improves patient outcomes. With every minute decrease in the response time, odds of dying during care decrease by almost two percent (AOR 0.981; CI 0.976 - 0.986; $p = <0.001$). Therefore, strategies to ensure timely EMS response should be developed in order to improve patient outcomes in Vinnytsia oblast, but also all across Ukraine.

This finding is consistent with established evidence in the field. For example, a study done in the United States found that the EMS response time of less than seven minutes reduces mortality from motor vehicle trauma by almost 50 percent [56]. A similar association was also shown in the EMS system in France, which is more similar to the Ukrainian system as it is also primarily physician-staffed [57]. Furthermore, the response time is not only associated with outcomes of trauma patients, but also with outcomes of patients who had an out-of-hospital cardiac arrest. A study's findings suggest that it is critical to ensure timely ambulance response to improve patient outcomes, reducing mortality and improving long term recovery of patients who had an out-of-hospital cardiac arrest [58].

The Vinnitsa EMS center should develop strategies to improve timeliness of their care. The study data suggests that the EMS average response time in Vinnytsia is 28.86 minutes. This is below government requirements as well as the recommendations of scientific literature [103,104]. One of the strategies that can be employed to shorten response time is to optimize the use of ambulances resources, especially considering the overall overuse of ambulances for non-emergency calls, described in section 5.1.1.. As mentioned previously, an optimization of ambulance resources can be achieved by the implementation of computer aided dispatch prioritization systems. Implementing such a system will help reduce arrival times and decrease mortality across a variety of emergency conditions [73].

5.2.3. An Emergency in a Public Place is a Risk for Mortality During EMS Care

The case-control study found that patients that have emergencies in public places have an increased risk of mortality. As the adjusted binary logistic regression showed that such patients are 2.5 times more likely to die during prehospital care, than patients that call the EMS from their home (AOR 2.658; CI 1.661 - 4.254; p = <0.001). Therefore, EMS in Vinnytsia and in Ukraine in general should pay closer attention to emergencies which happen in public places, so as to decrease mortality and improve patient outcomes.

Such increased mortality in public places may be caused by several factors. First, there could be a little training of bystanders in first aid care, therefore leading to little engagement during the incident. Active public participation in the provision of first aid is shown to significantly improve patient outcomes in different systems across the world [58,111,112]. To engage the public in the provision of first aid, the training should be made generally available, as well as should be a requirement for some professions and for children to graduate from school in other countries [113].

Moreover, lay providers should be legally protected from any adverse events that could occur during provision of first aid, by the so-called 'Good Samaritan Law' [114]. Second, another factor that may cause higher mortality in public places is the unavailability of accessible emergency alert systems, first aid kits, and automated external defibrillators (AED) in public places. Having such systems is shown to speed up EMS system activation, and initiation of care, hence allowing for a more timely response [115].

5.2.4. The Need for Call Categorisation

Patient's sex and age can influence prehospital treatment outcomes. The patient's sex was found to be associated with an increased risk of death during prehospital care. The study revealed that male patients are almost twice as more likely to die during prehospital care than female patients (AOR 2.063; CI 1.672 - 2.546; p = <0.001). While the patient's age was found to be a protective factor, with every year decrease in age, the odds of dying decreased by one percent (AOR 0.990; CI 0.983 - 0.997; p = 0.004). The results of the study are in line with published literature. As generally male patients are at a greater risk of mortality from both trauma and cardiac complaints. A major study with over 150,000 trauma patients conducted in the United States found that male patients are more likely to die from trauma than females (OR, 1.49; 95% CI, 1.39–1.59) [75]. The association of age with increased mortality from trauma was also established by many other researchers [53]. Assessing and acting on the risk of morality is a key strategy to improve system outcomes. Therefore, EMS response and provision of care to male and older age patients should be improved if outcomes are to be improved.

5.2.5. Use of Physicians on Ambulances

The level of care provided by a physician lead crew does not differ from the level of care provided by a feldsher lead crew. The study did not observe a significant difference between the qualification of the crew that provided care between the two study groups ($p = 0.068$). This is an interesting finding, which possibly indicates that physicians are not used to the full extent of their abilities within the EMS system.

Generally, literature suggests that the use of physicians on the prehospital level is not justified in the majority of cases. A pilot study comparing the effectiveness of physician-staffed ambulances to ambulances with nurses in Sweden showed that "most of the calls neither required the interventional skills of a physician, nor could they be performed..[in ambulance settings]" [67]. The use of physicians in prehospital settings only demonstrated improvements in outcomes for patients with an out-of-hospital cardiac arrest [57,68]. Therefore, it is recommended to review and develop more effective strategies for the use of physicians in the Ukrainian EMS, such that they can bring added value to the system.

5.3. Study Limitations

The result of this study should be interpreted with a consideration for certain limitations. First, some limitations arise from information biases, or so-called detection biases [116] biases caused by potential misclassification of cases and controls [116]. Such a bias may have occurred because the information on outcomes (death during treatment) was collected by the ambulance that provided the treatment to a particular patient. Consequently, there is a possibility that the ambulance crew may have classified patients as dead before the arrival of the ambulance, when in fact patients may have died during treatment provided by the ambulance. Published literature suggests that such misclassification of the cause of death happens in around 20 percent of cases [117]. Therefore, the study potentially did not account for 20 percent of cases. Further research is needed to more clearly identify the impact of such biases on the results of the study.

Additionally, another potential limitation is that the p-value significance threshold was set as 0.005 for this study, aiming at better reproducibility of findings and reducing detection of false positive association [90]. However, such a threshold may have possibly resulted in the under detection of some less significant, but still existing associations that influence prehospital mortality.

Another limitation of this study concerns the review of the EMS building blocks. The major source of information for this review was the Statistical report of the MoH from the number 22 'Report of ambulance stations. The data collection system for this report is not computerised, thus human error cannot be excluded. Moreover, this data is self-reported by the regional EMS centers. Hence, certain desirability biases may be present. Therefore, the results of analysis based on this particular source of data should be interpreted with caution.

Furthermore, neither the review of the EMS building blocks, nor the case-control study assessed the EMS system fully. Certain factors were not investigated within the scope of this study, which may significantly influence the system performance. Some of those factors include the knowledge and skills of the health workforce, the quality of the treatment protocols, the availability of lifesaving equipment and medicines in the ambulances. Therefore, further studies are needed to understand the influence of such factors that this study did not cover in terms of the system performance and patient outcomes.

5.4. Generalisability of Findings

The review of the EMS building blocks was done with the use of the national data, and therefore the findings are applicable to all oblasts of Ukraine. However, given the limitations stated above, the findings should be generalised with caution as the data can be biased or not accurate. At the same time, the case-control section of the study was done with the use of the Vinnytsia Oblast EMS Dispatch Centre, which automatically recorded the data that was included in the calls with patients, with a variety of chief complaints, as well as different age groups and genders. The data also contained calls from urban and rural settings, as well as was conducted by both physician and felsher lead crews. Therefore, such data should be applicable to all calls in the Vinnytsia oblast, and can be expanded to raise concerns regarding EMS centers with similar characteristics in other parts of Ukraine.

CONCLUSION

This research employed mixed methods aimed at assessing what should be changed in the Ukrainian EMS system to improve outcomes on the prehospital stage of severely ill or injured patients. First, to achieve the aim the assessment of the EMS system building blocks was utilized leveraging the use of a desktop review of the national regulations and statistics. Second, a matched case-control study was conducted to assess risk factors associated with the prehospital mortality, secondary data from the Vinnytsia EMS Dispatch Center was used for this part of the study. The results of both parts of the study were discussed, compared with the EMS systems in other countries, and relevant scientific recommendations were made to improve the patient outcomes in the Ukrainian EMS system.

With the use of the health system building blocks, several factors that potentially negatively influence patient outcomes were identified. The demand for EMS services in Ukraine appeared to be significantly higher than in other European countries. The Ukrainian EMS Dispatch Centers often do not filter or prioritize urgent and non-urgent calls, and in most cases try to respond to the calls by sending an ambulance. Furthermore, the non-conveyance rate in Ukraine appeared to be also significantly higher than in other European countries. All of this suggests that ambulances in Ukraine are used for more than just the provision of emergency care, potentially providing some of the services that are the function of the primary healthcare system. Such misuse of the EMS causes a dilution of already limited EMS resources, prolonged response times and the inability of the Ukrainian EMS system to provide appropriate services to patients that require it.

The health system building blocks review also discovered inequalities between the EMS systems in different oblasts of Ukraine. The per capita payments for EMS services from the central budget were found to vary from oblast to oblast, by more than three-fold. Implying that the level of care also can significantly vary within Ukraine.

Moreover, the utilization of the ambulance fleet also appeared to be significantly different between oblasts. Suggesting that the national standards of ambulance distribution or the adherence to them is not well established. Such a difference causes some oblasts to have shortages of ambulances, while others have more than they need. Furthermore, the EMS staff density was also found to be severely skewed to the urban areas of Ukraine, leaving the population that resides in rural areas with poorer access to emergency services.

The case-control part of this study discovered several factors that are statistically significant in association with increased mortality on the prehospital stage. First, the response time was found to be associated with mortality (AOR 0.981; CI 0.976 - 0.986; p = <0.001), indicating the need to further improve responsiveness of the EMS system in Ukraine, so as to improve outcomes. Second, patients that sustained emergencies in public places had increased mortality compared to the ones that had emergencies at home or at health care facilities (AOR 2.417; CI 1.667 - 3.505; p = <0.001). Indicating the need to raise the engagement of the public in the provision of first aid and expanding the availability of AEDs. Moreover, older (AOR 0.990; CI 0.983 - 0.997; p = 0.004) patients and males (AOR 2.063; CI 1.672 - 2.546; p = <0.001) were also found to have increased risk of mortality.

On the other hand, the case-control did not find any differences in patient mortality between the exposed and unexposed groups of several other hypothesised exposure factors. First, the mortality of the patients treated by a physician lead crew did not differ from patients treated by a feldsher lead crew. Indicating that use of the physicians in the emergency care system needs to be revised, to maximise their added value. Second, no differences in patient mortality between the time of the day and the season were found. This implies that the EMS in Vinnytsia provides equal quality of service all year round, despite temporal and seasonal changes in the EMS demand. This finding certainly should be acknowledged as an achievement of the service.

The study findings allow for making several evidence-based recommendations to inform policy formulation on how to reduce morality of acutely ill and injured patients in the prehospital stage. The recommendations will help strengthen the emergency care system in Ukraine, and as mentioned in literature review, this is critical to achieving universal health coverage. Moreover, a well functioning emergency care system decreases costs and improves impact in other parts of the health system [18]. However, one of the limitations of this research is that it overlooks several important components that are needed to ensure high quality emergency care, such as the health professional's education, adherence to treatment protocols, and availability of life-saving medicines and equipment on the ambulances. Therefore, further research is needed to evaluate those important components of the emergency care system in Ukraine.

Recommendations

- In order to reduce a relatively high demand for EMS services in Ukraine, it is recommended to initiate public awareness campaigns aimed at educating the public on when to use EMS and when to refer to other services.
- To increase efficiency of available EMS resources and improve response time, the EMS dispatch centers should be equipped with computer-aided call prioritisation software. The software can help dispatchers faster and more accurately determine the priority of the call and dispatch the nearest ambulance.
- To address inequalities in EMS finances between the oblasts, a new transparent system of payments for EMS services needs to be introduced.
- To address variation in the utilisation of ambulances between the oblasts, the standards for ambulance allocation need to be reviewed. New approaches for service planning should be introduced, including allocation of ambulances based on demand.
- To address shortages of EMS workforce in rural areas, strategies to attract healthcare workers to rural areas need to be developed on the national level. Such policies may potentially include expansion of the benefit package of rural workers or mandatory placements of medical students in rural areas after graduation.

- To reduce the high mortality rate of emergency patients in public places, several strategies should be employed to engage the public in early provision of first aid before the arrival of EMS. First, first aid courses should be a requirement for students to graduate from school, as well as mandatory for some public safety professions. Second, a 'Good Samaritan Law' should be introduced to protect first aid providers from liability. Third, publicly accessible first aid kids and AEDs should be made available in public places.
- Given that the outcomes of physician lead crews and feldsher lead crews do not differ, the use of physicians in the emergency care system needs to be reviewed in order to maximize their impact on patient outcomes.

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APPENDIX A. LIST OF TABLES

Table 4.1. Characteristic of matched cases and controls 43

Table 4.2. Odds ratio and 95 percent confidence intervals for risk of death during prehospital care 47

Table 4.3. Adjusted odds ratios and 95 percent confidence intervals for risk of death during prehospital care.. 49

Table 4.4. Controls used in the model compared with the source population 51

APPENDIX B. LIST OF FIGURES

Figure 1.1. WHO Health System Buildings Blocks 16
Figure 2.1. Matching of cases to controls on age and complaint 28
Figure 3.1. Organisational structure of emergency care system in Ukraine 31
Figure 3.2. Structure of the Vinnytsia EMS Center 31
Figure 3.3. Number of EMS responses and conveys per 10,000 population 33
Figure 3.4. Percentage of calls meeting response time standards by region in 2019 . 34
Figure 3.5. Per capita spendings on EMS by oblast in 2018 35
Figure 3.6. EMS personnel in Ukraine by profession, in 2019 36
Figure 3.7. Personnel per 10,000 population by type and urban/rural in 2019 37
Figure 3.8. Percentage of personnel by profession and urban/rural 37
Figure 3.9. UHU by oblasts of Ukraine 40
Figure 4.1. Inclusion of participants 41
Figure 4.2. Percent of missing values on variables included in to the analysis 42
Figure 5.1. Number of calls and ambulance responses per 10,000 population in Ukraine compared to countries 54
Figure 5.2. Ambulance non-convince rate in Ukraine compared to other countries.. 55

APPENDIX C. LETTER FROM VINNYTSIA EMERGENCY MEDICAL SERVICES CENTER

ВІННИЦЬКА ОБЛАСНА РАДА
КОМУНАЛЬНЕ НЕКОМЕРЦІЙНЕ ПІДПРИЄМСТВО «ТЕРИТОРІАЛЬНЕ МЕДИЧНЕ ОБ'ЄДНАННЯ «ВІННИЦЬКИЙ ОБЛАСНИЙ ЦЕНТР ЕКСТРЕНОЇ МЕДИЧНОЇ ДОПОМОГИ ТА МЕДИЦИНИ КАТАСТРОФ ВІННИЦЬКОЇ ОБЛАСНОЇ РАДИ»
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30.03.2020 № 01/453

Гаєвському
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З приводу Вашого запиту на інформацію від 23.03.2020 (вхідний № 78/01 від 26.03.2020) у відповідності з ч.4 ст.20 Закону України «Про доступ до публічної інформації» повідомляємо, що:

- запит стосується надання великого обсягу інформації
- потребує значних витрат часу та працівників Центру, частина яких внаслідок введених карантинних заходів працює віддалено. Тому, для підготовки повної відповіді та пошуку інформації, який здійснюється серед значної кількості даних, **строк розгляду Вашого запиту продовжено до 20 робочих днів**.

Відповідно до ст.23 Закону України «Про доступ до публічної інформації» запитувач інформації має право оскаржити несвоєчасне надання інформації, інші рішення, дії чи бездіяльність розпорядників інформації, що порушили законні права та інтереси запитувача.

Рішення, дії чи бездіяльність розпорядників інформації можуть бути оскаржені до керівника розпорядника, вищого органу або суду. Оскарження рішень, дій чи бездіяльності розпорядників інформації до суду здійснюється відповідно до Кодексу адміністративного судочинства України у порядку спрощеного позовного провадження (ст. 263 КАС України).

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