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ORIGINAL RESEARCH

# Volunteer Responder Interventions in Out-of-Hospital Cardiac Arrest in Urban, Suburban, and Rural Areas

Astrid Rolin Kragh , MSc; Mads Tofte Gregers , MD, PhD; Linn Andelius , MD, PhD; Anne Juul Grabmayr , MD; Louise Kollander , MD; Victor Elnegaard Kjærulf, MD; Julie Samsøe Kjølbye, MD; Annam Pervez Sheikh, MD; Annette Kjær Ersbøll , MSc, PhD; Fredrik Folke , MD, PhD; Carolina Malta Hansen , MD, PhD

**BACKGROUND:** Patients with out-of-hospital cardiac arrest (OHCA) in rural areas experience longer emergency response times and have lower survival rates compared with patients in urban areas. Volunteer responders might improve care and outcomes for patients with OHCA specifically in rural areas. Therefore, we investigated volunteer responder interventions based on the degree of urbanization.

**METHODS AND RESULTS:** We included 1310 OHCA cases from 3 different regions in Denmark where volunteer responders had arrived at the OHCA location. The location was classified as urban, suburban, or rural according to the Eurostat Degree of Urbanization Tool. A logistic regression model was used to examine associations between the degree of urbanization and volunteer responder arrival before emergency medical services, cardiopulmonary resuscitation, or defibrillation. We found the odds for volunteer responder arrival before emergency medical services more than doubled in rural areas (odds ratio [OR], 2.60 [95% CI, 1.91–3.53]) and suburban areas (OR, 2.05 [95% CI, 1.56–2.69]) compared with urban areas. In OHCA cases where volunteer responders arrived first, odds for bystander cardiopulmonary resuscitation was tripled in rural areas (OR, 3.83 [95% CI, 1.64–8.93]) and doubled in suburban areas (OR, 2.27 [95% CI, 1.17–4.41]) compared with urban areas. Bystander defibrillation was more common in suburban areas (OR, 1.53 [95% CI, 1.02–2.31]), where almost 1 out of 4 patients received bystander defibrillation, compared with urban areas.

**CONCLUSIONS:** Volunteer responders are significantly more likely to arrive before emergency medical services in rural and suburban areas than in urban areas. Patients with OHCA received more cardiopulmonary resuscitation in rural and suburban areas and more defibrillation in suburban areas than in urban areas.

**Key Words:** emergency responders ■ out-of-hospital cardiac arrest ■ volunteers

Volunteer responder programs for out-of-hospital cardiac arrest (OHCA) have been implemented in many communities, including Denmark, to increase bystander cardiopulmonary resuscitation (CPR) and defibrillation before the arrival of emergency medical services (EMS), as recommended by international guidelines.<sup>1–7</sup>

In Denmark, volunteer responders are either lay people or off-duty professionals who are dispatched

to perform CPR and defibrillation before the arrival of EMS.<sup>2</sup> The proportion of patients receiving CPR and defibrillation administered by random bystanders or activated volunteer responders has been observed to increase with extended EMS response times, and the chance of bystander defibrillation has been associated with the number of volunteer responders arriving before EMS.<sup>2,8</sup>

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## RESEARCH PERSPECTIVE

### What Is New?

- We observed that volunteer responders arrived before emergency medical services more often in rural and suburban areas compared with urban areas.
- When volunteer responders arrived before emergency medical services, the likelihood of bystander cardiopulmonary resuscitation increased significantly, with a 3-fold higher odds of bystander cardiopulmonary resuscitation in rural areas and 2-fold higher odds in suburban areas, compared with urban areas.

### What Question Should Be Addressed Next?

- This study underscores the crucial role of volunteer responders, particularly in rural and suburban regions, and points to a need for tailoring volunteer responder programs in relation to the degree of urbanization.

## Nonstandard Abbreviations and Acronyms

**OHCA** out-of-hospital cardiac arrest

Furthermore, a lower chance of return of spontaneous circulation and 30-day survival rate have been reported for patients in rural areas compared with patients in urban areas.<sup>9–11</sup> Conversely, a lower density of registered volunteer responders and longer volunteer response times are expected in rural areas compared with urban areas, as there are fewer people available in the community. Whether volunteer responder systems work equally well across areas with different degrees of urbanization and whether different measures should be taken to account for differences in population density when implementing volunteer responder programs is unknown. Understanding the potential impact of volunteer responders according to the degree of urbanization may help inform public health authorities and decision-makers to optimize volunteer responder programs across communities.

This study aims to investigate volunteer responder intervention according to the degree of urbanization (urban, suburban, and rural).

## METHODS

### Study Design and Setting

This retrospective, observational study uses prospectively collected data from the Danish volunteer

responder cohort and the Danish OHCA Registry.<sup>12</sup> The Danish volunteer responder program was implemented in the Capital Region in 2017 and was introduced nationwide in 2020.<sup>2</sup> A smartphone app alerts the nearest 20 volunteer responders within a radius of 5000 meters from the location of the presumed OHCA. This radius was extended from 1800 meters to 5000 meters in May 2021. Volunteer responders can either accept or reject an alarm. If an alarm is accepted, the volunteer responder will be directed to go either directly to the OHCA location to perform CPR (1 out of 5 volunteer responders) or to retrieve an automated external defibrillator (AED) and proceed to the OHCA location (4 out of 5 volunteer responders). By August 2023, more than 165 000 volunteer responders were registered, corresponding to approximate 27 500 volunteer responders per 1 million inhabitants.

We used the Strengthening the Reporting of Observational Studies in Epidemiology checklist when writing the manuscript.<sup>13</sup> The data that support the findings of this study are available from the corresponding author upon reasonable request.

## Data Sources

### Danish OHCA Registry

This study includes data on OHCA from the Danish OHCA Registry. In accordance with the Utstein guidelines for reporting OHCA, the registry has collected data on all EMS-treated OHCA patients in Denmark since 2001.<sup>14</sup> We used the following parameters for inclusion in this study: patient outcome as 30-day survival, bystander CPR (performed by either lay people or volunteer responders), bystander defibrillation (performed by either lay people or volunteer responders), ambulance response time, patient age and sex, and region of the OHCA.

### Volunteer Responder Questionnaire

All volunteer responders receive a follow-up questionnaire 90 minutes after an alarm (Data S1). The questionnaire consists of 21 questions. Volunteer responders are asked whether they accepted the alarm, arrived at the OHCA scene before EMS, their mode of transportation, whether or not they performed CPR, and whether they brought or used an AED. Volunteer responders also are asked to rate the immediate psychological impact they experienced and any physical injuries.<sup>15,16</sup> Volunteer responders who do not answer the questionnaire are contacted by email and telephone.

We used data from the questionnaire to determine whether volunteer responders arrived at the OHCA scene before EMS and the transportation mode they used.

## Study Population

We included non-EMS-witnessed OHCA from 3 different regions in Denmark: the Capital Region of Denmark (for the period November 1, 2018 to May 14, 2019), the Central Denmark Region (for the period November 1, 2018 to December 31, 2020), and the North Denmark Region (for the period February 14, 2020 to December 31, 2020). We included OHCA where volunteer responders accepted the alarm, arrived at the OHCA scene, and completed the postmission questionnaire.

## Emergency Medical Services and Degree of Urbanization

The Capital Region of Denmark covers an area of 2561 km<sup>2</sup> and has 1 855 084 inhabitants (720 inhabitants per km<sup>2</sup>). The Central Denmark Region covers 13 008 km<sup>2</sup> and has 1 332 048 inhabitants (102 inhabitants per km<sup>2</sup>), and the North Denmark Region covers 7886 km<sup>2</sup> and has 590 439 inhabitants (75 per km<sup>2</sup>).<sup>17</sup> Each region has 1 medical dispatch center served by ambulances and physician-staffed units. The medical dispatch centers are manned by trained health care professionals who provide dispatcher-assisted CPR instructions in OHCA cases and can access live video streaming to assist guidance in CPR.<sup>18</sup> All emergency dispatch centers use the same dispatch protocol.

## Geographical Analysis and Study Exposure

Municipalities were classified as urban, suburban, or rural using the Eurostat Degree of Urbanization Tool.<sup>19</sup> The tool was revised in 2011 by the European Commission's Directorates-General for Regional and Urban Policy, and for Agriculture and Rural Development, Eurostat, and the Joint Research Centre, together with the Organisation for Economic Co-operation and Development. Each exact OHCA location was geographically mapped with QGIS Version 3.18.2 and coded as urban, suburban, or rural.<sup>20</sup> The OHCA in each area were matched with their respective volunteer responder survey replies.

## Study Outcomes

The primary study outcome is volunteer responder arrival before EMS. Secondary outcomes are bystander CPR and defibrillation.

## Statistical Analysis

The categorical variables are presented as counts and percentages and continuous variables as medians with interquartile ranges or mean values with SDs. Associations between the degree of urbanization and volunteer responder arrival before EMS, the number of

volunteer responders arriving before EMS, bystander CPR, and bystander defibrillation were analyzed using a logistic regression model. The associations are presented as odds ratios (ORs) with 95% CIs. The associations were also analyzed using relative risk available in [Tables S1](#) and [S2](#). The Kruskal–Wallis test was used to test the statistical significance between distances according to the degree of urbanization. The results are considered significant if the 2-sided *P* value is <0.05. The SAS Enterprise Guide Version 7.1 for Windows and R studio were used to manage and analyze the data. To identify potential confounding variables, a directed acyclic graph model was created ([Figure S1<sup>21</sup>](#)). No confounders were identified as no variables affected both our exposure and outcomes.

## Ethics

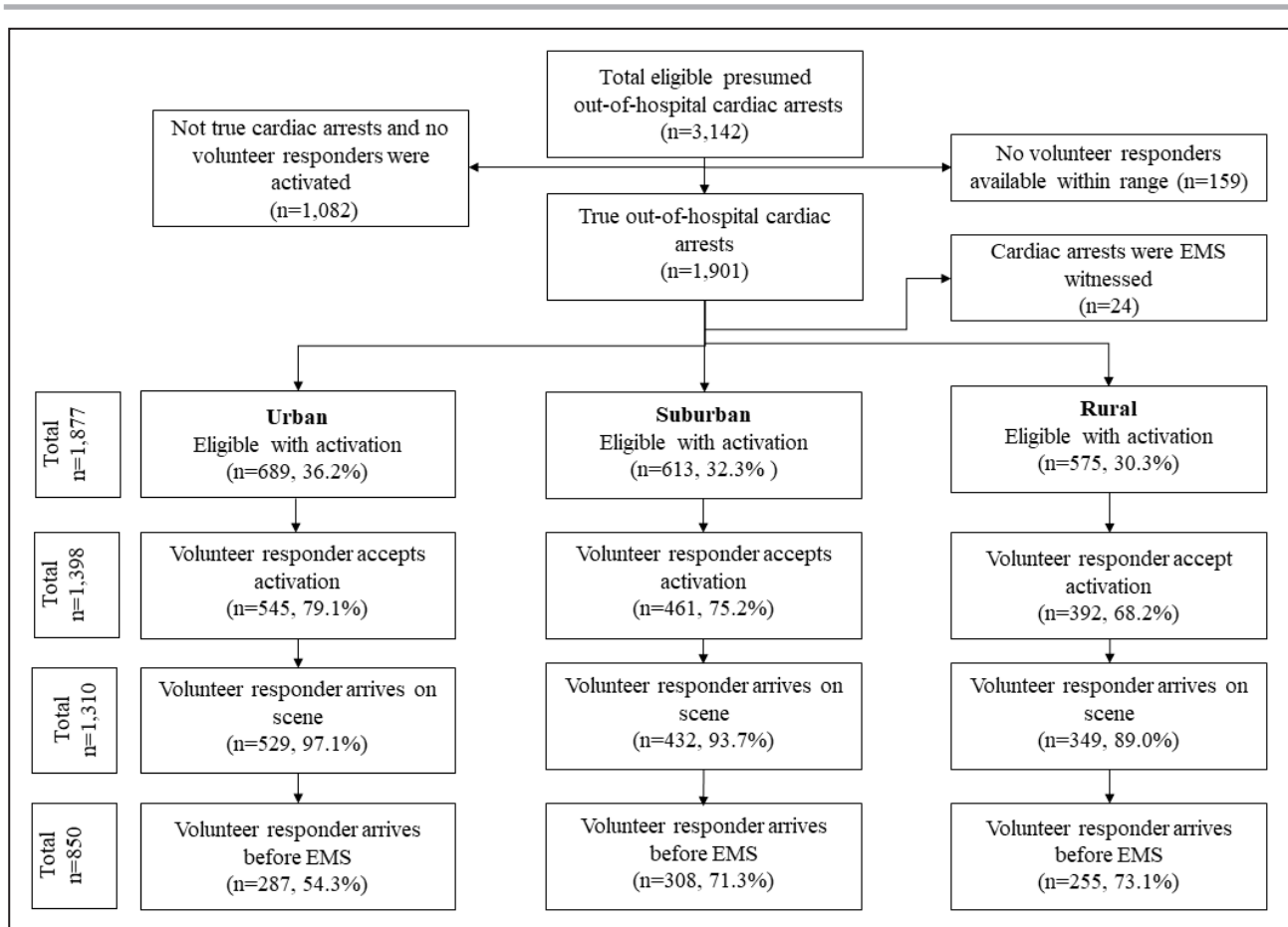
This study used data derived from the volunteer responder survey in the Capital Region of Denmark. The Danish project HeartRunner received approval from the National Board of Health (Journal No. R-20051145, 2012–58-0004). At registration, volunteer responders consent that their information is registered and used for research purposes. We obtained and stored OHCA data and volunteer responder data according to the rules of, and the legislation governing, the Danish Data Protection Agency (P-2021-670 and P-2021-82). Furthermore, the study was approved by the Danish Patient Safety Authority (R-23046855). According to Danish law, registry-based studies do not require approval from an ethics committee.

## RESULTS

We included 1310 confirmed OHCA from 3 different regions in Denmark (see [Figure 1](#)). In total, 5416 volunteer responders arrived at OHCA patients ([Figure S2](#)). The characteristics of the OHCA are displayed in [Table 1](#). The characteristics of the volunteer responders are available in [Table S3](#). The median numbers of alarms and of responding, accepting, and arriving volunteer responders are displayed in [Table 2](#). Of all volunteer responders, 99% had completed basic life support training, and 53.8% had completed training within the latest year of registration ([Table S4](#)).

## Volunteer Responder Arrival Before EMS According to Degree of Urbanization

Of the 1310 OHCA, most (n=529, 40.4%) occurred in urban areas, followed by suburban (n=432, 33.0%) and rural (n=349, 26.6%) areas. The number of volunteer responders who accepted an alarm was higher in urban areas compared with suburban and rural areas ([Table 2](#)).



**Figure 1. Flow chart for inclusion of OHCA.**  
EMS indicates emergency medical services.

We found the odds for volunteer responder arrival before EMS more than doubled in rural areas (OR, 2.60 [95% CI, 1.91–3.53]) and suburban areas (OR, 2.05 [95% CI, 1.56–2.69]) compared with urban areas (see Figure 2). Furthermore, we observed more OHCA cases in suburban and rural areas, where more than 3 volunteer responders arrived before EMS, compared with urban areas (for suburban areas: OR, 1.81 [95% CI, 1.33–2.46], for rural areas: OR, 1.51 [95% CI, 1.08–2.10]) (see Figure 2).

### Bystander Interventions According to Degree of Urbanization

The large majority of OHCA cases, 1176 cases (89.9%), received bystander CPR, and 184 cases (14.1%) received bystander defibrillation before EMS arrival. In the 850 OHCA cases where volunteer responders arrived before EMS, the odds for bystander CPR were 3 times higher in rural areas (OR, 3.83 [95% CI, 1.64–8.93]), where 97.3% received bystander CPR, and 2 times higher in suburban areas (OR, 2.27 [95% CI, 1.17–4.41]), where 95.5% received bystander CPR, compared with urban areas where 90.2% received bystander CPR (see Figure 3).

We observed a statistically significant increase in the odds for bystander defibrillation in suburban areas (OR, 1.53 [95% CI, 1.02–2.31]) where almost 1 out of 4 patients received bystander defibrillation (23.1%), compared with urban areas, where 16.4% received bystander defibrillation. No statistically significant difference was found for bystander defibrillation in rural areas compared with urban areas (see Figure 3). In OHCA cases where volunteer responders arrived after EMS, patients received bystander CPR and defibrillation less frequently (Figure S3).

Bystander CPR and defibrillation increased according to the number of volunteer responders arriving before EMS across population density (Figures S4 and S5).

### Volunteer Responder Transportation Modes

Volunteer responders' mode of transportation differed by the degree of urbanization. Most volunteer responders traveled by car in suburban and rural areas, whereas volunteer responders mostly traveled by foot in urban areas (see Figure 4). We observed slightly

**Table 1. Out-of-Hospital Cardiac Arrest Characteristics According to Degree of Urbanization**

Characteristic	Urban, n=529 (40.4%)	Suburban, n=432 (33.0%)	Rural, n=349 (26.6%)	Overall, n=1310	Missing
Age, y, median (Q1, Q3)	72 (62–80)	73 (63–81)	73 (62–81)	73 (62–81)	35
Sex, male, n (%)	343 (67.3)	293 (69.3)	228 (66.7)	864 (67.8)	35
Sex, female, n (%)	167 (32.8)	130 (30.7)	114 (33.3)	411 (32.2)	35
ROSC, n (%) <sup>*</sup>	167 (31.6)	145 (33.6)	99 (28.4)	411 (31.4)	1
Initial shockable rhythm, n (%)	101 (19.1)	97 (22.5)	57 (16.3)	255 (19.5)	0
Private home, n (%)	415 (78.5)	366 (84.7)	294 (84.5)	1075 (82.1)	1
Bystander witnessed, n (%)	279 (52.8)	228 (52.8)	178 (51.0)	685 (52.3)	1
Bystander CPR, n (%) <sup>†</sup>	453 (85.6)	398 (92.6)	325 (93.1)	1176 (89.9)	2
Volunteer responder as CPR provider, n (%) <sup>‡</sup>	152 (53.2)	215 (69.8)	160 (62.8)	527 (62.1)	1
Bystander defibrillation, n (%) <sup>§</sup>	63 (11.9)	77 (17.8)	44 (12.6)	184 (14.1)	1
30-d Survival, n (%)	73 (14.3)	69 (16.4)	43 (12.6)	185 (14.5)	38
Volunteer responder before EMS, n (%) <sup>  </sup>	287 (55.4)	308 (71.8)	255 (76.4)	850 (66.4)	29
Ambulance response time in min, median (IQR)	6 (3)	7 (5)	8 (7)	7 (5)	29
Distance from volunteer responder to OHCA in meters, median (IQR)	406.1 (395.1)	594.2 (542.3)	696 (776.3)	533 (574.4)	0
Distance from volunteer responder to automated external defibrillator in meters, median (IQR)	257.1 (312.3)	330.0 (405.0)	408.3 (470.1)	307 (386.0)	0

CPR indicates cardiopulmonary resuscitation; EMS, emergency medical services, IQR, interquartile range; OHCA, out-of-hospital cardiac arrest; and ROSC, return of spontaneous circulation.

<sup>\*</sup>Did the patient at any point receive ROSC before arrival at hospital?

<sup>†</sup>Bystander CPR before ambulance arrival, either by volunteer responder or bystander.

<sup>‡</sup>Bystander CPR by volunteer responder in OHCA cases where volunteer responders arrived first, n=850.

<sup>§</sup>Defibrillation before ambulance arrival, either by volunteer responder or random bystander.

<sup>||</sup>At least 1 volunteer responder arrived before EMS.

longer median EMS response times in rural areas (8 minutes) compared with suburban and urban areas (7 and 6 minutes, respectively; see Table 2). The proportion of volunteer responders guided to AED <250 m was highest in urban areas but remained high across population densities (Figure S6).

## DISCUSSION

This study investigated volunteer responder intervention according to the degree of urbanization in Denmark. We found overall high proportions of

bystander CPR across degree of urbanization; 9 out of 10 patients received bystander CPR, and 1 out of 7 received bystander defibrillation before EMS arrival.

Volunteer responder arrival before EMS occurred significantly more often in rural and suburban areas compared with urban areas. When volunteer responders arrived before EMS, patients in suburban and rural areas were more likely to receive bystander CPR compared with urban areas, whereas patients in suburban areas were more likely to receive bystander defibrillation.

Community volunteer responder programs are associated with a greater chance of bystander

**Table 2. Number of Alerted Volunteer Responders According to Degree of Urbanization**

	Urban	Suburban	Rural
Median number of alerted volunteer responders for each OHCA <sup>*</sup> (IQR)	20 (0)	20 (10)	10 (17)
Median number of volunteer responders who responded to the OHCA alarm (IQR) <sup>†</sup>	11 (6)	9 (8)	6 (10)
Median number of volunteer responders who accepted the OHCA alarm (IQR) <sup>‡</sup>	4 (5)	4 (4)	3 (5)
Median distance (meters) between volunteer responder and OHCA scene	406.9	594.2	696.2
Median number of volunteer responders who arrived at the OHCA scene (IQR) <sup>§</sup>	3 (4)	3 (1)	2 (4)
Median number of volunteer responders who arrived at the OHCA scene before EMS (IQR)	1 (2)	1 (3)	1 (2)
OHCA where volunteer responders accepted an alarm, n (%)	529 (40.4)	432 (33.0)	349 (26.6)

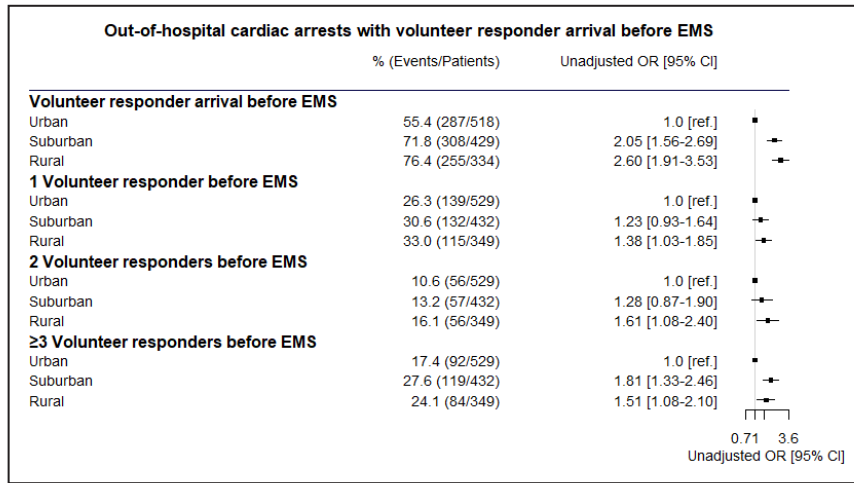
EMS indicates emergency medical services, IQR, interquartile range; and OHCA, out-of-hospital cardiac arrest.

<sup>\*</sup>Median number of alerted volunteer responders for all 1877 non-EMS-witnessed OHCA.

<sup>†</sup>Median number of volunteer responders who responded to the alarm for all 1877 non-EMS-witnessed OHCA.

<sup>‡</sup>Median number of volunteer responders who accepted the alarm in 1398 non-EMS-witnessed OHCA where volunteer responders accepted.

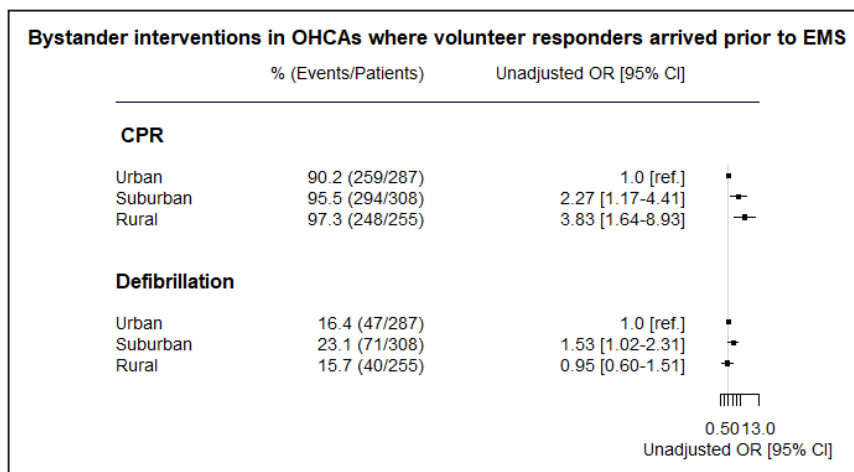
<sup>§</sup>Median number of volunteer responders who arrived at the non-EMS-witnessed OHCA in 1310 OHCA where volunteer responders arrived.



**Figure 2.** Forest plot reporting odds ratios for the association of volunteer responders arriving before emergency medical services and degree of urbanization. EMS indicates emergency medical services; and OR, odds ratio.

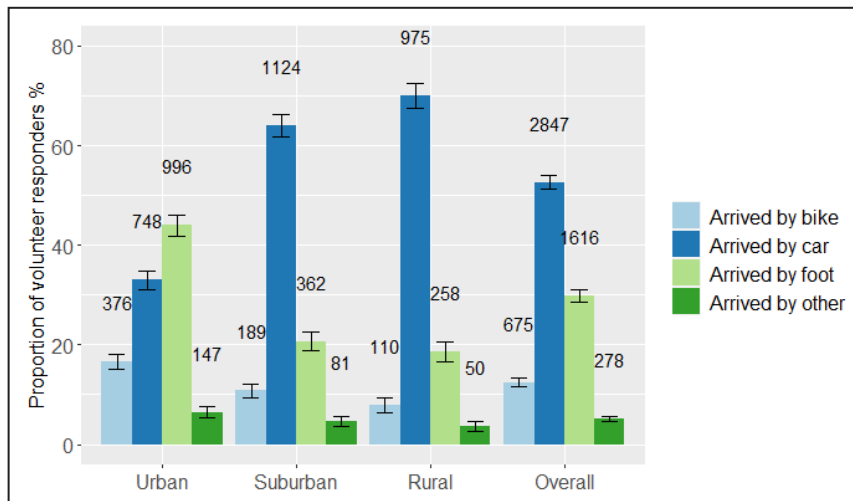
CPR, bystander defibrillation, and 30-day survival.<sup>22</sup> However, increasing AED use and defibrillation are still challenging.<sup>23</sup> A recent study from Italy indicated that volunteer responders rarely arrived before EMS (13.4%), and those who arrived before EMS had median shorter distances (<1 km) to the OHCA.<sup>24</sup> The study found that volunteer responders who were equipped with an AED had an increased likelihood of arriving before the EMS. Although our findings suggest that volunteer responder systems may help mitigate disparities in bystander interventions across degrees of urbanization, equipping volunteer responders with portable AED systems may further improve bystander defibrillation rates in rural areas.<sup>25</sup>

In Denmark, rural areas have a significantly higher yearly incidence of OHCA and lower 30-day survival compared with both suburban and urban areas.<sup>26</sup> The Danish volunteer responder system alerts up to 20 volunteer responders within a radius of 5 km, regardless of region; however, the optimal activation radius for alerting volunteer responders is currently unknown. Although the proportion of OHCA cases where volunteer responders accepted an alarm and arrived on scene was lower in rural areas compared with suburban and urban settings, volunteer responders managed to arrive before the EMS more often in rural areas. Implementing volunteer responder programs in rural areas may help mitigate disparities and improve bystander CPR rates.



**Figure 3.** Forest plot reporting odds ratios for the association of bystander interventions (cardiopulmonary resuscitation and defibrillation) and degree of urbanization in 850 OHCA cases where volunteer responders arrived before emergency medical services. CPR indicates cardiopulmonary resuscitation; EMS, emergency medical services; OHCA, out-of-hospital cardiac arrest; and OR, odds ratio.

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**Figure 4. Volunteer responders' choice of transportation according to degree of urbanization.**

Bar chart presenting proportions of volunteer responder transportation modes according to degree of urbanization.

Although EMS response times generally are short in Denmark, we found volunteer responders mainly preferred to travel by car in rural areas, enabling them to go faster. A longer activation radius in rural and suburban areas according to the preferred mode of transportation may improve the presence of volunteer responders in nonurban areas. Unfortunately, our study does not include data on time of volunteer responder arrival versus EMS arrival. A recent study from Sweden found volunteer responders on average arrived 4 minutes before the EMS, even in areas with high population density. Investigating whether the time gap between volunteer arrival and EMS arrival varies depending on the degree of urbanization could be relevant for future research.

We observed an increase in both bystander CPR and bystander defibrillation in OHCA cases where volunteer responders arrived before EMS. Conversely, in OHCA cases where volunteer responders arrived after EMS, patients received fewer bystander interventions. Nevertheless, volunteer responders can remain valuable and essential resources for EMS personnel and relatives of patients with OHCA even when they arrive after EMS, as they often provide emotional support for relatives during the resuscitation of their loved ones.<sup>27,28</sup> We found a significantly higher proportion of bystander defibrillation in suburban settings than in urban and rural settings. Despite densely placed AEDs in urban areas, urban areas often consist of numerous tall buildings and volunteer responders need to travel through traffic, which may delay their arrival. Further, EMS response times are short in urban areas making the likelihood of arrival before EMS lower. In rural areas, distances are longer and time from patient collapse to

volunteer responder arrival may be increased resulting in fewer patients with shockable rhythm.

The potential benefits of volunteer responder programs, particularly in nonurban settings, add to current guidelines from the American Heart Association, the European Resuscitation Council, and the International Liaison Committee on Resuscitation recommending mobile phone technology to engage volunteers in OHCA resuscitation.<sup>6,29</sup>

Our findings support that volunteer responders are a key component in the Danish health system's capability to deliver effective prehospital care to patients with OHCA. The bystander CPR rate in Denmark was 80% even before the introduction of the volunteer responder system.<sup>30</sup> This high rate is likely due to many Danes being trained in CPR and the use of dispatcher-assisted CPR.<sup>31</sup> In addition to assisting with resuscitation, volunteer responders may also help improve CPR quality as almost 1 out of 3 volunteer responders are health care educated. In fact, the arrival of volunteer responders to assist in turns is a relief to bystanders.<sup>28</sup> The results of the study point to a need for tailoring volunteer responder programs in relation to the degree of urbanization as AED density and the number of available volunteer responders within the activation radius may play an important role.

### Limitations of the Study

A limitation of this observational study is the inability to assess causal relationships. Data on whether volunteer responders arrived before EMS were reported by volunteer responders, which may not always be accurate. This study does not include data on time intervals



between volunteer responders' arrival and EMS arrival, which is a study limitation. However, we do provide granular data on how many volunteer responders were available, how many received an alarm, how many accepted the alarm and finally, how many arrived at the scene, which is a high degree of granularity compared with other systems.<sup>3,5</sup> We included data from 3 out of 5 regions in Denmark. Including all 5 regions would enable the use of a larger data set and would strengthen the study. However, the study had a catchment area of 65%, which is the majority of the population. We included different time periods because the Danish volunteer responder program was first enrolled in the Capital Region of Denmark in September 2017, and the remaining regions joined in 2019 and 2020. However, we do not expect any significant changes across these few years. Denmark is a high-performing community with many AEDs and volunteer responders, and a small rural population, which may limit the transferability of the study to other countries. However, our findings that volunteer responders may mitigate long EMS response times and low survival rates in rural areas may be of even greater importance the less populated a region is. Finally, due to a high probability of the outcomes, the ORs presented cannot be interpreted as risk ratios.

## CONCLUSIONS

Volunteer responders are significantly more likely to arrive before EMS in rural and suburban areas compared with urban areas. When volunteer responders arrived before EMS, we found increased bystander intervention in nonurban areas compared with urban areas, suggesting that volunteer responder intervention may be more substantial with decreasing population density.

## ARTICLE INFORMATION

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Folke: analysis and interpretation of data, revision of article. Carolina Malta Hansen: study conception and design, analysis and interpretation of data, revision of article. All authors have read and approved the final article.

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### Disclosures

None.

### Supplemental Material

Data S1  
Tables S1–S4  
Figures S1–S6

## REFERENCES

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