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BRIEF COMMUNICATION

Risk of Physical Injury for Dispatched Citizen Responders to Out-of-Hospital Cardiac Arrest

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BACKGROUND: Citizen responder programs are implemented worldwide to dispatch volunteer citizens to participate in out-of-hospital cardiac arrest resuscitation. However, the risk of injuries in relation to activation is largely unknown. We aimed to assess the risk of physical injury for dispatched citizen responders.

METHODS AND RESULTS: Since September 2017, citizen responders have been activated through a smartphone application when located close to a suspected cardiac arrest in the Capital Region of Denmark. A survey was sent to all activated citizen responders, including a specific question about risk of acquiring an injury during activation. We included all surveys from September 1, 2017, to May 15, 2020. From May 15, 2019, to May 15, 2020, we followed up on all survey nonresponders by phone call, e-mail, or text messages to examine if nonresponders were at higher risk of severe or fatal injuries. In 1665 suspected out-of-hospital cardiac arrests, 9574 citizen responders were dispatched and 76.6% (7334) answered the question regarding physical injury. No injury was reported by 99.3% (7281) of the responders. Being at risk of physical injury was reported by 0.3% (24), whereas 0.4% (26) reported an injury (25 minor injuries and 1 severe injury [ankle fracture]). When following up on nonresponders (2472), we reached 99.1% (2449). No one reported acquired injuries, and only 1 reported being at risk of injury.

CONCLUSIONS: We found low risk of physical injury reported by volunteer citizen responders dispatched to out-of-hospital cardiac arrest. Risk of injury should be considered and monitored as a safety measure in citizen responder programs.

Key Words: app ■ automated external defibrillator ■ cardiopulmonary resuscitation ■ lay rescuer ■ out-of-hospital cardiac arrest

Citizen responders volunteer to be alerted to participate in resuscitation when located near an out-of-hospital cardiac arrest (OHCA). They can be dispatched through smartphone applications (apps) or text messages and are guided to either start cardiopulmonary resuscitation (CPR) or to retrieve a publicly accessible automated external defibrillator (AED).[1–4] Citizen responder programs have been implemented in many countries and have varying requirements for registration.[5] Citizen responders can be laypeople, off-duty healthcare professionals, police, or firefighters.[4,5]

In Denmark, a citizen responder program was introduced in September 2017, which became nationwide in May 2020.[1] The program held ≈85 000 registered citizen responders in May 2020 (1545 per 100 000 inhabitants) and included both laypeople and off-duty healthcare professionals. Citizen responders need to travel quickly, potentially through traffic, to reach the person in cardiac arrest within the first minutes after collapse. That could put them at risk of accidents or physical injury. Little is known about the extent of risk of physical injury to which citizen responders are exposed. In a pilot study from the Capital Region of

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Denmark, <1% (n=6) reported physical injury or risk of physical injury when alerted to a nearby OHCA.[1] However, this study covered only a short period and, importantly, had no information for the ≈20% of the citizen responders who did not respond to the survey after activation. These nonresponders could represent a high-risk group since severe injury or hospitalization could be a reason for not answering the survey.

Activation of citizen responders has been associated with an increase in bystander CPR and defibrillation.[1,2,6,7] The American Heart Association and the European Resuscitation Council recommend activating citizen responders despite a very low level of evidence, and safety concerns for those involved are underlined.[8,9] In this observational study, we aimed to investigate the self-reported risk of physical injury for citizen responders who were dispatched to suspected OHCAs, including a systematic follow-up on nonresponders. We hypothesized that activation of citizen responders to OHCA resuscitation is associated with a low risk of physical injury.

METHODS

Study Setting and Design and Study Population

The data supporting our findings are available from the corresponding author upon reasonable request. This was an observational study based on self-reported surveys from citizen responders in the Danish citizen responder program (Heartrunner app[10]). To register, one needs to be at least 18 years of age, and prior CPR training is highly recommended but not mandatory. The study included surveys from the Capital Region of Denmark between September 1, 2017, and May 15, 2020. All citizen responders who either accepted or accepted and then declined the alarm were considered subjects of potential injury and included.

The Capital Region of Denmark has 1.8 million inhabitants and is served by 1 emergency dispatch center and a 2-tiered emergency medical services system. One ambulance and 1 physician-staffed vehicle are dispatched to presumed OHCAs. Citizen responders are activated for suspected OHCAs except in unsafe surroundings, traumatic OHCA, suicide, children <8 years of age, or when an AED is not indicated (eg, in nursing homes). The system locates citizen responders within 1.8 km from the cardiac arrest. If the alarm is accepted, the citizen responder is either guided directly to the OHCA to initiate CPR or to retrieve a publicly accessible AED and proceed to the OHCA location. The citizen responder program has been described in detail previously.[1]

Data Sources and Survey

Citizen responder information (sex, age, profession, CPR training, last updated position) and data from alarms (timestamps, locations, interactions with alarms) were collected from the app server. All dispatched citizen responders received a text message with a link to an electronic survey 90 minutes after activation (Table S1). In case of a missing response, an automatic reminder was sent the following day. The self-reported risk of physical injury was reported as a yes or no question. If the citizen responder said yes, the following question was asked: *On your way to the cardiac arrest location: (1) Were you at risk of physical injury or close to getting injured? (2) Did you suffer minor injuries without need of treatment/hospitalization? (3) Did you suffer severe injuries with need of treatment/hospitalization? (4) Other?* Responses were categorized into 3 groups post hoc: no injury, risk of physical injury, and injured (including both minor injuries without need of treatment/hospitalization and severe injuries in need of treatment/hospitalization).

On May 15, 2019, a randomized clinical trial was initiated in the Capital Region of Denmark (HeartRunner trial, www.clinicaltrials.gov: NCT03835403). As a safety precaution to this study, all survey nonresponders were followed up to ensure that no unreported injury occurred during activation. This follow-up is planned to continue until the end of the trial since nonresponders could represent a high-risk group if severe injury or hospitalization would be the reason for not answering the survey. Accordingly, from May 15, 2019, to May 15, 2020, all nonresponders received a third text message about a week after activation. In case of no reply, we identified those who had sent out an updated position from their app within 7 days after the alarm. This interaction with the app was interpreted as a sign of still being an active citizen responder. Citizen responders who had not sent out an updated position were contacted by text message, phone call, and e-mail. If we could not reach the responder after these efforts, no further attempts were made. However, all citizen responders could contact the research team via e-mail, and the citizen responder community on social media was frequently browsed for posts about injuries.

Statistical Analysis

Categorical values were presented as frequencies and percentages and continuous variables as medians with interquartile boundaries. Statistical significance for differences between categorical variables was tested with Fisher's exact test and the Kruskal-Wallis test for continuous variables. Distances between citizen responder, AED, and OHCA location were calculated as straight-line distances using the

position of the citizen responder when accepting the alarm. These coordinates were not available for alarms between September 1, 2017, and February 11, 2018, and this period was excluded from the distance calculations. Citizen responders could be dispatched and included in data more than once, but all responses were accounted for as exclusive observations. Data were analyzed in SAS 9.4 M5 (SAS Institute Inc., Cary, NC).

Ethics

Data storage was approved by the Data Protection Agency (Journal no. P-2021-82). The HeartRunner randomized controlled trial was presented to the regional scientific ethics committee, who concluded that the study did not require a scientific ethics approval and could be initiated without further approval (Journal no. 17018804). Citizen responders agree to share their latest updated location and agree to be contacted by the research team and share data reported in the survey to research when registering as volunteers.

RESULTS

Almost 40 000 citizen responders were registered in the Capital Region of Denmark in May 2020. Between September 2017 and May 2020, a total of 30 008 citizen responders were activated to 1751 suspected OHCAs, and 53.5% responded to the alarm. In 1665 of the alarms, 9574 either accepted or accepted and then declined the alarm and received the survey. The overall response rate was 81.8% (7834), of which 93.6% (7334) answered the question regarding physical injury and were included in this study (Figure 1). Of the 7334 responders, 76.2% (4188) had been dispatched once, 17.2% (944) twice, 4.6% (253) 3 times, and 1.5% (110) >3 times. Characteristics of included citizen responders are shown in Table. Characteristics of nonresponders are presented in Table S2.

Self-Reported Risk of Injury

Of the 7334 activated citizen responders who answered the questions about potential injuries, no injury was reported by 99.3% (7281). Twenty-four (0.3%) reported having been at risk of injury, and 26 (0.4%) experienced some degree of injury during the activation. One injury in need of hospital treatment was reported (an ankle fracture acquired while running to the OHCA location), and 25 minor injuries not requiring treatment or hospitalization (no further details were given about these injuries). The severe injury was reported by the citizen responder in the survey, but the authors received this information through 4 independent sources (survey, social media, direct contact, and colleagues). Nine citizen responders used the free text option to describe their experience, and 8 of them were categorized as being at risk of injury. The most frequent risk was unsafe conduct through traffic, such as crossing the road despite a stop sign. Most activated citizen responders traveled by car or foot, and the risk of injuries was reported more frequently when citizen responders traveled by foot. There was no significant difference in straight-line distances between OHCA, AED, and the responders among the 3 groups. Police/firefighter/ambulance personnel were more likely to report injuries compared with other professions, although the observed numbers were small (Table). After activation, 99.1% (7189) in the no-injury group wanted to continue as a responder. The respective number for the risk of injury group was 100% (24) and 96.2% (25) for the group who reported an injury. A citizen responder could withdraw from the program without answering the survey and could, in that case, not be accounted for.

When the randomized clinical trial (HeartRunner trial, www.clinicaltrials.gov: NCT03835403) started, a systematic follow-up of nonresponders was initiated. In this period, 2472 citizen responders were activated to 342 presumed OHCAs, and 82.1% answered the survey. To evaluate the risk of injury for the remaining 17.9%, an additional text message was sent out about a week after activation. This resulted in additional 105 replies (23.8% of missing). Of these responders, 83.2% reported having arrived after emergency medical services. Of the 337 citizen responders who did not respond to the follow-up text message, 265 sent out an updated position from their app within 7 days after the alarm. Finally, the remaining 70 citizen responders who had not replied or sent an updated position were contacted by additional text messages, phone calls, and/or e-mails. Forty-seven (67.1%) were successfully reached. One person reported to have been at risk of injury, and none reported injuries. Consequently, we managed to obtain contact or locate activity from 99.1% of all activated citizen responders, resulting in 23 (0.9%) citizen responders whom we could not reach (Figure 2).

DISCUSSION

This study investigated the risk of physical injuries among a large cohort of citizen responders dispatched to suspected OHCAs through a smartphone app. We found a minimal risk of <0.5% of physical injuries requiring treatment or hospitalization and a low risk of minor injuries without need of hospital treatment. When following up on nonresponders, we found that most had arrived at the OHCA location after emergency medical services, and only 1 had

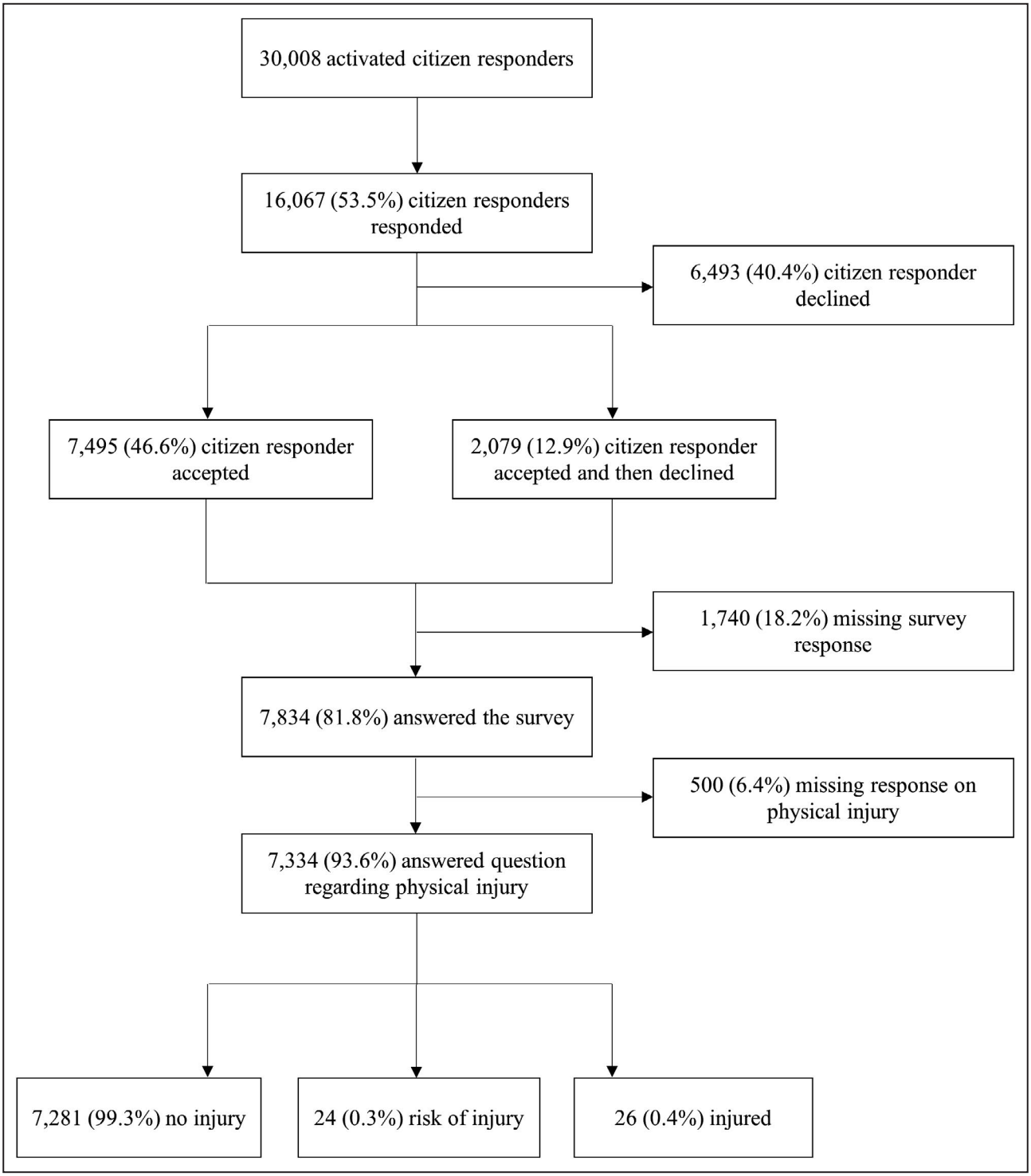

Figure 1. Flowchart illustrating selection of included citizen responders.

been at risk of injury. We could verify activity among 99.1% of all activated citizen responders, but 0.9% were not reached despite substantial efforts. These results indicate that it is safe for citizen responders to be dispatched to OHCA resuscitation in the Capital Region of Denmark, and that a survey is an effective tool to capture potential risk of physical harm among dispatched citizen responders.

This study provides novel and important information regarding safety for citizen responders activated through an app. The American Heart Association and the European Resuscitation Council

Table. Characteristics of Activated Citizen Responders

	No Injury (N=7281)	Risk of Injury (N=24)	Reported Injury (N=26)	*P* Value
Age, y, median (Q_1, Q_3)	37 (27, 47)	27 (21, 37)	30 (25,42)	0.002
Sex, male, n (%)	3792 (52.1)	14 (58.3)	11 (42.3)	0.51
Profession, n (%)				0.013
Healthcare professional	2108 (29.0)	7 (29.2)	4 (15.4)	
Police, ambulance, or firefighter	716 (9.8)	1 (4.2)	7 (26.9)	
Student	985 (13.5)	7 (29.2)	6 (23.1)	
Other	3472 (47.7)	9 (37.5)	9 (34.6)	
Previous CPR training, n (%)	7201 (98.9)	23 (95.8)	25 (96.2)	0.11
CPR training <1 y at registration, n (%)	3753 (51.6)	15 (62.5)	14 (53.8)	0.56
Median distance* from citizen responder to suspected OHCA, meters, median (Q_1, Q_3)	518 (294, 829)	454 (261, 759)	371 (188, 606)	0.10
Median distance* from citizen responder to AED and to suspected OHCA, meters, median (Q_1, Q_3)	613 (416, 878)	754 (454, 1060)	573 (337, 698)	0.21
Arrived at the location of suspected OHCA,† n (%)	5716 (91.6)	24 (100.0)	20 (80.0)	0.044
Means of transportation,‡ n (%)				0.005
Car	2379 (41.6)	6 (25.0)	6 (30.0)	
Bicycle	924 (16.2)	5 (20.8)	3 (15.0)	
By foot	2384 (41.7)	12 (50.0)	9 (45.0)	
Other	29 (0.5)	1 (4.2)	2 (10.0)	
Arrived before EMS,§ n (%)	1682 (43.9)	4 (40.0)	7 (58.3)	0.64

AED indicates automated external defibrillator; CPR, cardiopulmonary resuscitation; EMS, emergency medical services; OHCA, out-of-hospital cardiac arrest; and Q_1, Q_3, interquartile boundaries.

*Calculated as straight-line distances.

†The denominator included 6289 who were asked if they arrived at the OHCA (Q6 in the survey, Table S1).

‡The denominator included 5760 who answered that they arrived at the OHCA (Q6 in the survey, Table S1).

§The denominator included 3830 who were asked if they arrived before the EMS (Q8 in the survey, Table S1).

recommend implementing citizen responder programs as potential resources to decrease time to resuscitation and improve survival for patients with OHCA.[8,9] Therefore, such programs are increasingly implemented worldwide and involve many laypeople and off-duty healthcare professionals who volunteer to participate in OHCA resuscitation.[4,5] Focus has primarily been set on investigating the effect of citizen responder programs on bystander interventions and patient outcomes,[1,2,6,11,12] but the potential risk of physical injury for citizen responders is largely unknown.[1] Physical safety is central when dispatching volunteers in a citizen responder program. Measuring the physical impact through a survey allows citizen responders to report potential adverse events. However, it might result in an incomplete assessment of the program if not all citizen responders complete the survey. In a worst-case scenario, a citizen responder who acquires a severe or fatal injury and is not able to respond to the survey would be reported as a nonresponder. It is therefore important to establish systematic follow-up for nonresponders. Follow-up is resource consuming, but an overall evaluation of a citizen responder program should balance the psychological and physical risk for citizen responders and the potential to improve survival for patients following OHCA.

Our study found no significant difference in distances between OHCA, AED, and citizen responders for the 3 groups. However, we calculated distances as straight line, which most likely have underestimated the distances compared with real-world route distances. Previous studies have shown that route distances are ≈1.3 to 2.4 times longer than straight-line distances,[13,14] and routes for citizen responders might be unwalkable because of water or terrain.[15] Traveling a longer distance could increase the risk of getting injured. We found a higher frequency of reported risk of injury when responders traveled by foot, and some reported that they had traveled through traffic in an unsafe manner. Informing citizen responders to ensure their safety when accepting an alarm is highly recommended.

Despite a high survey response rate of >80%, this study was limited by a noncomplete response rate. Despite substantial efforts to follow up on nonresponders, we cannot conclude that the few citizen responders we could not reach were not injured. This risk is assumed to be small since the only severe injury was reported to

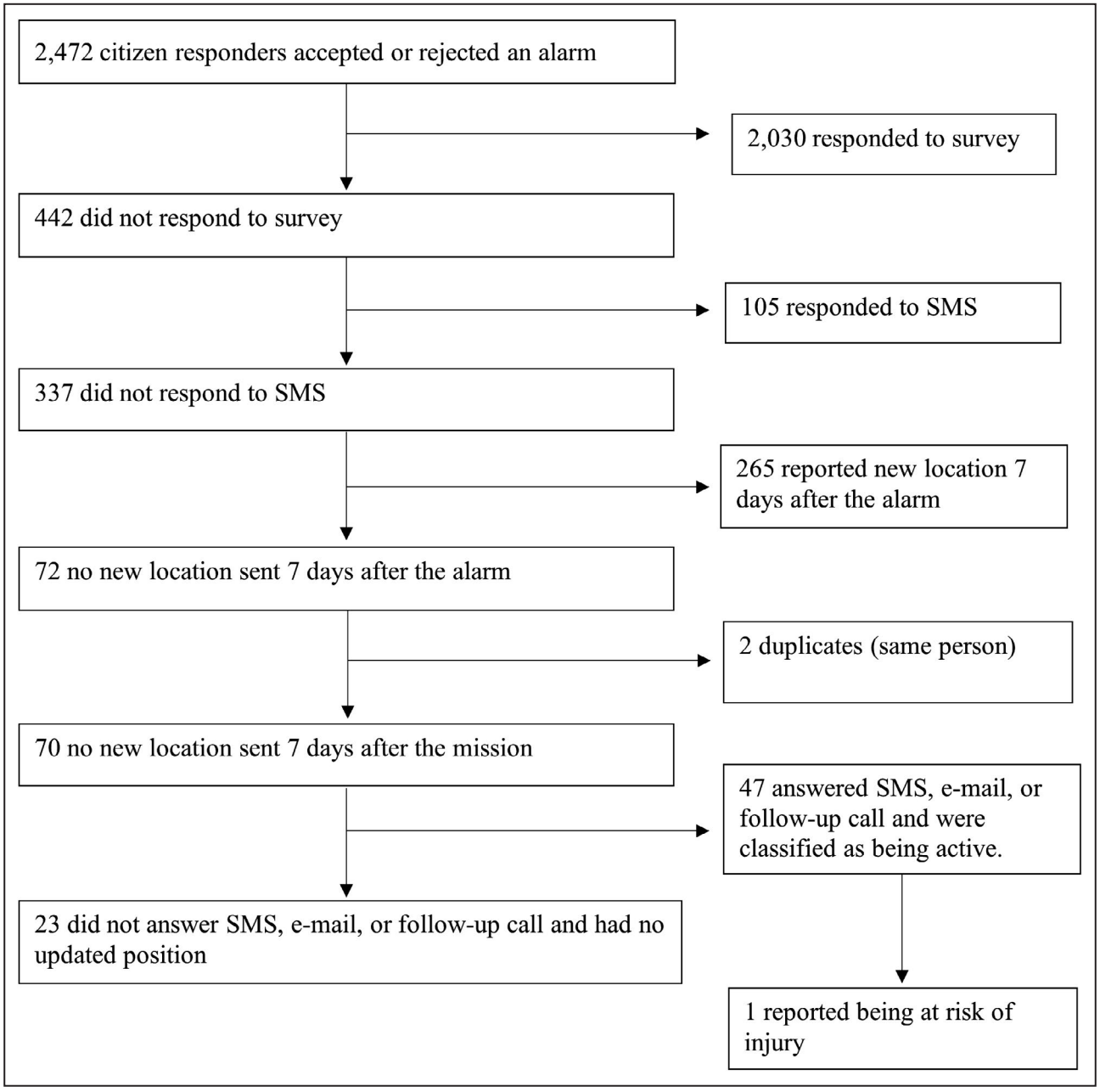

Figure 2. Flowchart illustrating follow-up of nonresponders between May 15, 2019, and May 15, 2020.

our team by 4 independent sources. Furthermore, we did not identify any nonreported injuries when following up on nonresponders. More than 80% of the nonresponders did not arrive at the OHCA location before emergency medical services, which was a more significant proportion than responders. This could indicate that a reason for not answering the survey was because the citizen responder never arrived at the OHCA location. Finally, the survey was self-reported and not validated for interpretation of risk of injury among citizen responders. However, the aim of this study was to assess perceived risk of injury by each individual, which could include individual differences in the perception of risk. The results were still limited by the possibility of incorrect reporting. The observed differences in risk of injury/injury should be viewed with caution since the number of events was low and significant differences in age and profession could be attributable to chance rather than reflecting specific characteristics. Since citizen responders are dispatched only on the basis of location (and not profession), it is unlikely that profession is a predictor for acquiring an injury. The follow-up for nonresponders was, in some cases, also conducted several months after activation. Experiencing a severe

injury is likely remembered by the responder. However, being at risk of getting injured could have been forgotten, leading to recall bias, and cause an underestimation of the risk of physical injuries in our study.

CONCLUSIONS

This study indicates a low risk of physical injuries reported by citizen responders dispatched to OHCA resuscitation. The risk of injury is an important aspect of citizen responder activation and should be closely monitored as a safety measure. Systematic follow-up on activated citizen responders is recommended to evaluate a citizen responder program.

ARTICLE INFORMATION

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Supplementary Material

Tables S1–S2

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SUPPLEMENTAL MATERIAL

Table S1. Survey.

Survey sent to all citizen responders whose app had confirmed the alarm. The original survey is in Danish. This is the English translation.

Start question

Q0 Did you accept the alarm?
Yes (Go to Q1)
No (Go to Q50)

Accept questions:

Q1 Did you try to retrieve a defibrillator?
Yes (Go to Q2)
No (Go to Q3)

Q2 Did you succeed in retrieving a defibrillator?
Yes (Go to Q4)
No (Go to Q3)

Q3 Why did you not succeed in retrieving a defibrillator?
1) The alarm did not include enough information (Go to Q4)
2) The defibrillator was not accessible (Go to Q4)
3) The defibrillator I was directed to was already taken (Go to Q4)
4) There were technical problems with the app (Go to Q4)
5) I was not directed to a defibrillator (Go to Q4)
6) Other reason (Go to Q4)

Q4 Did you try to reach the cardiac arrest location?
Yes (Go to Q6)
No (Go to Q5)

Q5 Why did you not try to reach the cardiac arrest location?
1) I was unavailable to help (Go to Q17)
2) I noticed the alarm too late (Go to Q17)
3) It was too far away (Go to Q17)
4) There were technical problems with the app (Go to Q17)
5) Other reason (Go to Q17)

Q6 Did you succeed in reaching the victim?
1) Yes, by foot (Go to Q8)
2) Yes, by bike (Go to Q8)
3) Yes, by car (Go to Q8)
4) Yes, with other transportation (Go to Q8)

5) No (Go to Q7)

Q7 Why did you not succeed in reaching the victim?
1) The alarm did not contain sufficient information (Go to Q17)
2) I aborted the alarm when I saw the emergency personnel (Go to Q17)
3) There were technical problems with the app (Go to Q17)
4) Other reason (Go to Q17)

Q8 Did you reach the victim before the emergency personnel?
Yes (Go to Q9)
No, I arrived after the emergency personnel (Go to Q9)

Q9 Had cardiopulmonary resuscitation been initiated when you arrived?
Yes (Go to Q11)
No (Go to Q10)

Q10 Did you initiate cardiopulmonary resuscitation?
Yes (Go to Q12)
No (Go to Q12)

Q11 Who performed cardiopulmonary resuscitation?
1) Emergency personnel (Go to Q12)
2) Other bystander (Go to Q12)

Q12 Did you or any other citizen responder attach a defibrillator to the patient?
Yes (Go to Q13)
No (Go to Q14)

Q13 Did the defibrillator deliver a shock to the patient?
Yes (Go to Q14)
No (Go to Q14)

Q14 Did you perform cardiopulmonary resuscitation?
Yes (Go to Q15)
No (Go to Q16)

Q15 What kind of cardiopulmonary resuscitation did you perform?
1) Only chest compressions (Go to Q17)
2) Only ventilations (Go to Q17)
3) Both chest compressions and ventilations (Go to Q17)

Q16 Why did you not perform cardiopulmonary resuscitation?
1) The patient was not in cardiac arrest (Go to Q17)
2) The patient was conscious (Go to Q17)
3) Someone else performed cardiopulmonary resuscitation (Go to Q17)
4) Other reason (Go to Q17)

Q17 Did you sustain any physical injuries or were you at risk of physical injuries on your way to the cardiac arrest location?

Yes (Go to Q20)
No (Go to Q18)

Q18 One could experience psychological impact when helping with cardiac arrest resuscitation. What psychological impact did the experience have on you?

1) I was not affected (Go to Q19)
2) Mildly affected (Go to Q19)
3) Moderately affected (Go to Q19)
4) Severely affected, but no need for follow-up by healthcare personnel (Go to Q19)
5) Severely affected, with need for follow-up by healthcare personnel (Go to Q19)

Q19 Do you want to continue as a citizen responder?

1) Yes (Go to END)
2) No (Go to END)
3) In doubt (Go to END)

Q20 On your way to the cardiac arrest location:

1) Were you at risk of physical injury or close to getting injured? (Go to Q18)
2) Did you suffer minor injuries without need for treatment/hospitalization? (Go to Q18)
3) Did you suffer severe injuries with need for treatment/hospitalization? (Go to Q18)
4) Other? (Go to Q18)

END If you feel a need for debriefing or follow-up by healthcare personnel, please send an e-mail to *hjerteloeber.den-praehospitale-virksomhed@regionh.dk.*
Please note that we cannot reveal any information or outcome about the cardiac arrest patient. Thank you for your participation.

Decline questions:

Q50 We ask you to answer two short questions to help us improve the citizen responder system. What was the reason you did not accept the alarm?

1) I was unavailable to accept the alarm (Go to Q51)
2) I did not feel comfortable about helping (Go to Q51)
3) I expected the emergency personnel to get there before me (Go to Q51)
4) Technical problems (Go to Q51)

Q51 Do you want to continue as a citizen responder?

1) Yes (Go to END2)
2) No (Go to END2)
3) In doubt (Go to END2)

END2 If you wish to contact us, please send an e-mail to *hjerteloeber.den-praehospitale-virksomhed@regionh.dk*.

Table S2. Characteristics of Activated Citizen Responded Who Answered the Question Regarding Physical Injury and Citizen Responders who Did not Respond to the Survey or Did not Answered the Question Regarding Physical Injury.

	Responders N=7,334	**Non-responders** N=2,205	**P-Value**	**Missing**
Age, median (Q_1, Q_3)	37 (27, 47)	33 (25, 44)	<0.001	35
Sex, male, n (%)	3,818 (52.1)	1,111 (50.4)	0.17	35
Profession, n (%)			<0.001	35
Healthcare	2,121 (28.9)	638 (28.9)		
Police, ambulance, or firefighter	724 (9.9)	204 (9.3)		
Student	998 (13.6)	389 (17.6)		
Other	3,491 (47.6)	974 (44.2)		
Previous CPR training, n (%)	7,252 (98.9)	2,174 (98.6)	0.26	35
CPR training < 1 year at registration, n (%)	3,785 (51.6)	1,101 (49.9)	0.17	35

Median distance* from citizen responder to suspected OHCA, meters, median (Q_1, Q_3)	517 (294, 827)	601 (355, 997)	<0.001	35
Median distance* from citizen responder to AED and to suspected OHCA, meters, median (Q_1, Q_3)	613 (416, 878)	656 (453, 939)	<0.001	35

* Calculated as straight-line distances. AED indicate automated external defibrillator; CPR, cardiopulmonary resuscitation; OHCA, out-of-hospital cardiac arrest; Q_1, Q_3, interquartile boundaries