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Clinical paper

A brisk walk—Real-life travelling speed of lay responders in out-of-hospital cardiac arrest

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Abstract

Background: Defibrillation by public Automated External Defibrillators (AEDs) before EMS arrival is associated with high survival rates. Previous recommendSations suggest that an AED should be placed within a 1–1.5 min "brisk walk" from a cardiac arrest. Current guidelines hold no recommendation. The real-time it takes for a volunteer to retrieve an AED in a public setting has not been studied.

Methods: Global Positioning System data and Geographical Information Systems methods were used to track the movement of mobile phone dispatched lay responders in two large Swedish areas. The distance and the travelling time were calculated from when the lay responder received the call, until they were within 25 m from the coordinate of the suspected OHCA sent by the dispatch centre.

Results: During 7 months, a total of 2176 persons were included in the final analysis. The median travelling speed was 2.3 (IQR = 1.4–4.0) metres per second (m/s) among all cases with a response time of 6.2 min. The corresponding travelling distance was 956 m (IQR = 480–1661). In the most densely populated areas (>8000 inhabitants/km^2) the response time was 1.8 m/s compared to 3.1 in the least densely populated areas (0 –1500 inhabitants/km^2).

Conclusion: The median travelling speed of all lay responders dispatched to suspected OHCAs was 2.3 m/s. In densely populated areas the travelling speed was 1.8 m/s. This can be used as support in guidelines for planning placement of AEDs, in simulation studies, as well as in configuration of mobile-based dispatch systems.

Keywords: Out-of-hospital cardiac arrest, Resuscitation, Public access defibrillation, Lay responders, ESCAPE-NET

Introduction

Defibrillation before the arrival of the emergency medical system (EMS) is associated with high survival rates in out-of-hospital cardiac arrest (OHCA).[1] Automated External Defibrillators (AEDs) accessible to the public are vast in numbers in industrialized areas, and online AED-registers have emerged (such as heartsafe.org.uk,hjertestarter.dk, hjartstartarregistret.se). Still, only a few per cent of all OHCAs are defibrillated by a public AED.[2] Several studies have addressed the obstacles for AED use such as mismatch in accessibility and placement.[3,4] Dispatch of nearby lay responders via mobile phone technology may be one way to increase the use of public AEDs.[5–7]

To facilitate defibrillation by lay responders within the first minutes, an AED must be available nearby.

Little is known about the time it takes to fetch an AED in real-life. The 2006 American Heart Association (AHA) policy recommendation[8] suggested that AEDs should be placed within a 1–1.5 min "brisk walk" from a cardiac arrest. This recommendation was based on indoor studies of specific locations such as casinos[9] and airports.[10] Several studies have translated the 1–1.5 min brisk walk to a 100 m Euclidian – or straight-line – distance[3,11–13] or the shortest walking route.[14,15] In a

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recent study from the UK, the shortest pedestrian walk was used. The authors assumed that a "brisk walk" would be 4 miles per hour (mph) or 1.79 m per second (m/s).[16] The authors called for studies on how fast bystanders are capable of travelling to better understand the operating radius of an AED.[16]

Smartphones with built-in global positioning systems (GPS) bring new possibilities to study the real-life travel of lay responders. The aim of this observational study was to investigate the travelling speed and response time for lay responders dispatched to a suspected OHCA in relation to population density.

Methods

Study design

This was an observational study on retrospective data. Data from the Heartrunner system in Region Stockholm and Region Västra Götaland in Sweden during 9 months (May 3rd 2018–Feb 3rd 2019) were used. The lay responders in the Heartrunner system were dispatched to the suspected OHCA by a mobile phone application. When dispatched, the address of the suspected OHCA, route directions, and available AEDs from the Swedish AED-register were shown on a map. During a mission, the lay responders' real-time locations and walking route were tracked by GPS. The system was active during daytime (07:00–23:00).

Setting

We covered suspected OHCAs during daytime in two regions with mixed urban and rural areas: Region Stockholm with an area of 6519 km^2 and a population of 2,3 million, and Region Västra Götaland, with an area of 23 942 km^2 and 1,7 million inhabitants. Together the two areas cover about 40% of Sweden's population (4 million). There is one emergency dispatch centre in each region. A total of 175 (145 on weekends) ambulances run in the two areas, whereof 56% versus 62% run round-the-clock in Stockholm and Västra Götaland respectively. At the end of the study period there was 2821 AEDs registered in Stockholm, and 3118 in Västra Götaland.

The Heartrunner system

The Heartrunner system dispatches lay responders to suspected OHCAs by a smartphone application. A volunteer with training in CPR downloads the mobile phone application. After registration and activation measures, they are available for dispatch to suspected OHCA. Upon registration, the lay responder states their year of birth, their occupation and yes/no if they have an accessible AED. The dispatcher at the Emergency Dispatch Centre (EDC) activates the system manually in cases of suspected OHCA. Up to thirty lay responders are located within a distance of 1320 m, and either requested to run immediately to perform CPR, or to fetch an AED in each suspected OHCA. The lay responder can either choose to accept the mission or decline. When the mission is accepted, the location and route directions to the suspected OHCA and nearby AEDs are displayed on a map. The system has been described more in detail elsewhere.[17]

Mapping

The lay responders were, after accepting a mission, positioned every few seconds (median 12, IQR = 10–21). The coordinates were plotted on a map, and the response time was calculated from the timestamp of the responder's first position until they reached the location of the suspected OHCA. All events that continued within the total time (i.e. engage with the application, reading message and map, locating, finding and retrieving an AED, as well as relocating to the victim) were included. The "location of the OHCA" was defined as the coordinates sent out from the dispatch centre, which equals to the centre of a building. A buffer zone of 25 m radius around the location was defined as the last arrival spot, so as to leave some space for where the actual patient was located. The distance was measured from the coordinates where the lay responders accepted the mission via all points until they reached the 25-m buffer zone (Fig. 1). The travelling speed measured in metres per second (m/s) was defined as the response time divided by the distance travelled. Population density was calculated in "Small Areas for Market Statistics" (SAMS) – areas created by Statistics Sweden, which contains population statistics and are similar to census tracts.

Survey answers

An online survey was sent as a text message link to all lay responder 90 min after an alert. The answering rate of the survey was 74% among all dispatched lay responders and 93% among those who reached the scene of the suspected OHCA. The lay responders answered questions about their actions taken as a result of the alert, such as, – if they reach the scene, – if they performed CPR, and – if they retrieved an AED.

Construction of groups

Dependent on their location and distance to the OHCA and available AEDs, the lay responders in the Heartrunner system are dispatched to either go directly to the suspected cardiac arrest to provide CPR or to fetch a nearby AED. By default, the lay responders are assigned to fetch an AED in 5:1 ratio (5 dispatched to fetch an AED and 1 to perform CPR). Several lay responders who were dispatched to fetch an AED did however report in the survey that they instead ran directly to perform CPR (51%). To handle this cross over, the lay responders were classified according to the survey answer. Lay responders assigned to fetch an AED who reported that they did not try to fetch an AED, were moved to the CPR-group and vice versa.

Statistical analysis

Descriptive statistics are presented as counts and percentages for categorical variables and medians and quartiles (q1, q3) for continuous variables. All statistical and geographical analyses were conducted in R statistical software version 3.6.0 using the sp[18] and sf package.[19]

The study is a sub-study of the SAMBA-trial (ClinicalTrials.gov Identifier: NCT02992873), which was approved by the regional ethics board in Stockholm (2016-1531-31/4, 2019-03315).

Results

In 1406 cases of suspected OHCA during the study period, 9058 lay responders accepted the mission. Of those, 2206 (22%) reached the scene of the suspected OHCA. Lay responders who had less than two registered coordinates (n = 30, 1,4%) were excluded. After exclusion,

Fig. 1 – GPS-points displaying two lay responders travelling route, where red dots indicate a lay responder who went directly to the suspected OHCA, and blue triangles indicate a lay responder who went via an AED.

the final analytic sample consisted of 2176 lay responders that reached the scene. Of these, 1430 (66%) chose to run directly to perform CPR, while 746 (34%) tried to fetch an AED (Fig. 2).

Travelling time and distances (Table 1)

Among all the lay responders that reached the scene, the median speed was 2.3 m/s (IQR = 1.4−4.0). The corresponding response time was 6.2 min (IQR = 4.3−9.2) and the median distance was 956 m (IQR = 480−1661). The median travelling speed was similar between the CPR and AED group (2.3 vs 2.4 m/s) while the response time was slightly longer in the AED group (5.8 min vs. 7.0) due to longer distance (890 vs. 1087 m).

The travelling speed differed depending on population density. In the most densely populated areas (>8000 inhabitants/km^2) the median travelling speed was 1.8 m/s (IQR = 1.2−2.5) compared to 3.1 m/s (IQR = 1.8−4.9) in the sparsely populated areas (0 −1500 inhabitants/km^2).

The number of lay responders who reached the scene within 3 min was 138 (10.9%) in the CPR-group, and 48 (7.3%) in the AED-group. The corresponding numbers within 5 min was 488 (38.7%) and 182 (27.5%). Almost 80% reached the scene within 10 min (Fig. 3).

Characteristics of the lay responders (Table 2)

The characteristics of lay responders that reached the scene of the suspected OHCA are presented in Table 1. The median age of lay responders reaching the scene was 37 years (29−45), 51.4% were males, and 27.9% had stated that they had access to an AED. Of the lay responders, 31.6% reported that their occupation was health workers, 8.1% were fire fighters, police, or other security personnel, and 8.3% were students, while the majority, 52%, reported other occupations.

Discussion

This study reports real-life response times of lay responders in cases of suspected cardiac arrest. The main finding is the travelling speed of the lay responders of 2.3 m/s among all lay responders and 1.8 m/s in densely populated areas.

This finding can be compared to previously reported calculated measures. Our estimate of 2.3 m/s (5.15 mph) is somewhat faster than previously used estimates of travelling speed. However, in the most densely populated areas the travelling speed was 1.8 m/s. This group

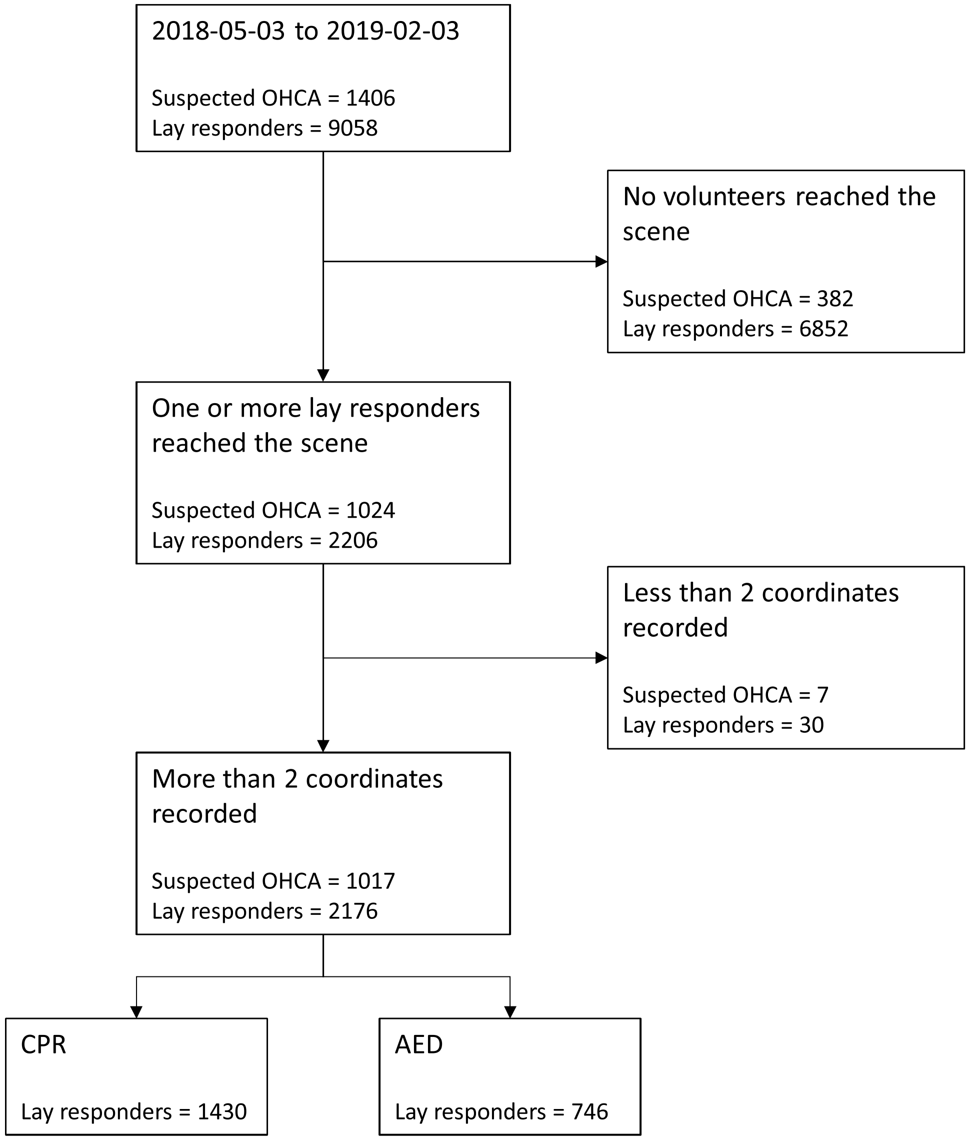

Fig. 2 – Events of suspected OHCA and associated lay responders during 9 months. Cases selected for analysis.

had the narrowest distribution, indicating homogeneity, which suggests that they may have travelled by foot.

Fig. 4 shows our estimates by population density in comparison with previously used estimates in other studies. The assumed travelling speed (4 mph, 1.79 m/s) used by Deakin et al.[16] is the same as our estimate in the most densely populated areas. Suggesting that this is a reasonable assumption for travelling speed by foot.

A recent study from Ticino, Switzerland had a similar aim to this study.[20] Judging by the travelling speed, their application users seem to mainly travel by some kind of vehicle (only 15% had a travelling speed under 3 m/s). Therefore, a comparison between their results and ours is hard to do.

The first 2006 AHA recommendation was to place an AED within a 1–1.5 min "brisk walk" from a cardiac arrest[8] (3 min round-trip).

Studies have reported survival rates up to 70% if a shock is provided within a 3-min time frame [9]. In light of the 3-min time frame, Our estimate of 1.79 m/s (4 mph) in densely populated areas would result in a travelling distance of 322 m, which is the same as Deakin et al.[16] Other assumed travelling speeds used by Ainsworth's et al.[21] 1.56 m/s (3.5 mph) and Osterman's et al.[22] 1.38 m/s (3.1 mph) would correspond to a distance of 280 m and 248 m respectively.

Several studies used a zone of 100-m radius[3,11,12] as an estimate of the maximum round-trip distance that a layperson can transport an AED within 3 min; this corresponds to a speed of 1.1 m/s, resulting in a distance of 198 m. This estimate is likely unfair in the sense that the real world likely includes some delay times, for instance to fetch the AED.

Although the 2006 AHA recommendation of a 1–1.5-min brisk walk may be helpful for public access defibrillation program planners, it does not provide much guidance for simulation studies to find optimal placement for AEDs. A more realistic travelling time, together with more sophisticated distance calculations, as used by Deakin et al.,[16] Karlsson et al.,[14] and Søndergaard et al.[15] may therefore yield better estimates for the potential of public access defibrillation.

Table 1 – Travelling speed, response time and distance travelled among lay responders reaching the scene of the suspected OHCA.

	All n = 2176	CPR n = 1430	AED n = 746
All (n = 2176)			
Meters/second, median (Q1, Q3)	2.3 (1.4, 4.0)	2.3 (1.4, 3.9)	2.4 (1.5, 4.0)
Response time, median (Q1, Q3)	6.2 (4.3, 9.2)	5.8 (4.1, 8.2)	7.0 (4.8, 10.6)
Distance, median (Q1, Q3)	956 (480, 1661)	890 (450, 1568)	1087 (564, 1920)
Men (n = 1113)			
Meters/second, median (Q1, Q3)	2.6 (1.6, 4.3)	2.7 (1.6, 4.4)	2.6 (1.7, 4.2)
Time, median (Q1, Q3)	6.0 (4.2, 8.5)	5.5 (4.0, 7.6)	6.8 (4.6, 9.9)
Distance, median (Q1, Q3)	1030 (534, 1738)	977 (494, 1670)	1140 (600, 1948)
Women (n = 1051)			
Meters/second, median (Q1, Q3)	2.0 (1.3, 3.5)	2 (1.3, 3.4)	2 (1.4, 3.8)
Time, median (Q1, Q3)	6.5 (4.4, 9.9)	6.0 (4.2, 8.9)	7.6 (5.0, 11.8)
Distance, median (Q1, Q3)	889 (446, 1571)	808 (409, 1417)	1029 (517, 1908)
Population density			
8000 + /km^2 (n = 574)			
Meters/second, median (Q1, Q3)	1.8 (1.2, 2.5)	1.7 (1.1, 2.6)	1.9 (1.3, 2.4)
Time, median (Q1, Q3)	5.8 (4.1, 9.1)	5.3 (3.8, 7.9)	6.5 (4.6, 10.2)
Distance, median (Q1, Q3)	627 (376, 1108)	571 (330, 1014)	742 (452, 1195)
4000−7999/km^2 (n = 503)			
Meters/second, median (Q1, Q3)	2.4 (1.5, 4.1)	2.4 (1.4, 4.0)	2.4 (1.5, 4.1)
Time, median (Q1, Q3)	6.7 (4.5, 9.6)	5.8 (4.2, 8.4)	8.1 (5.7, 11.5)
Distance, median (Q1, Q3)	1057 (530, 1818)	983 (471, 1646)	1274 (711, 2067)
1500−4000/km^2 (n = 566)			
Meters/second, median (Q1, Q3)	2.5 (1.5, 4.1)	2.4 (1.5, 4.0)	2.7 (1.5, 4.2)
Time, median (Q1, Q3)	6.0 (4.2, 8.9)	5.8 (4.1, 7.7)	6.8 (4.4, 10.4)
Distance, median (Q1, Q3)	1003 (496, 1708)	958 (457, 1595)	1143 (565, 1956)
0−1500/km^2 (n = 533)			
Meters/second, median (Q1, Q3)	3.1 (1.8, 4.9)	3 (1.8, 4.8)	3.4 (2.0, 4.9)
Time, median (Q1, Q3)	6.4 (4.5, 9.0)	6.2 (4.3, 8.6)	6.8 (4.8, 10.0)
Distance, median (Q1, Q3)	1257 (693, 2015)	1125 (673, 1851)	1490 (740, 2382)

However, our estimate should be held in the light of the fact that the lay responders in the Heartrunner system are highly motivated to reach the scene as fast as possible. The median age of the lay responders in the present study was 37 years; therefore, our estimate of travelling speed is likely not representative for the entire population. But nevertheless, it might be the best estimates to date.

Response times

Most of the lay responders were not able to reach the scene within the critical 3−5 min. This is likely due to the fairly long distances they had to travel. Several factors are of importance for the lay responder to arrive with an AED before EMS. One crucial factor is the density of both available AEDs and number of educated citizens/designated lay responders. To minimize the difference in response time between those who run directly to perform CPR and those who fetch an AED, the AEDs need to be located close to the location of the cardiac arrests. In Stockholm, as in many other parts of the world, there is a mismatch between where the majority of cardiac arrests occur (at home) and where the AEDs are located (in public locations).[4] This mismatch may increase the distance the lay responders have to travel. Observational data from Japan[23] and Denmark[15] found an association between the number of AEDs near the cardiac arrest and the probability of bystander defibrillation.

AED availability also depends on the hour of the day, where a large part of the public AEDs are available only at business hours.[3] If AEDs were more often placed outside buildings, the travelling distances, and therefore also the time to reach the scene, would likely decrease.

Another factor decreasing the distances would be to increase the number of lay responders participating in similar lay responder systems, especially in areas where there is still a small number of lay responders.

Compliance with assignment

One interesting finding in our analysis is that the majority of lay responders travelled directly to the suspected cardiac arrest to perform CPR. The Heartrunner system dispatches on a 5:1 basis to fetch an AED. We expected the group aiming to fetch AEDs would be much larger, which was not the case. One plausible reason for this is that lay responders may think that they will not reach the scene before the arrival of EMS/first responders if they run the extra distance past the AED, since the travelling distance is longer. It is also possible that lay responders overestimate the effect of CPR alone. Although CPR is a stable predictor of survival[24] the effect of defibrillation is much stronger.[1] We may need to further emphasize the importance of early defibrillation in CPR courses and in information to the general public.

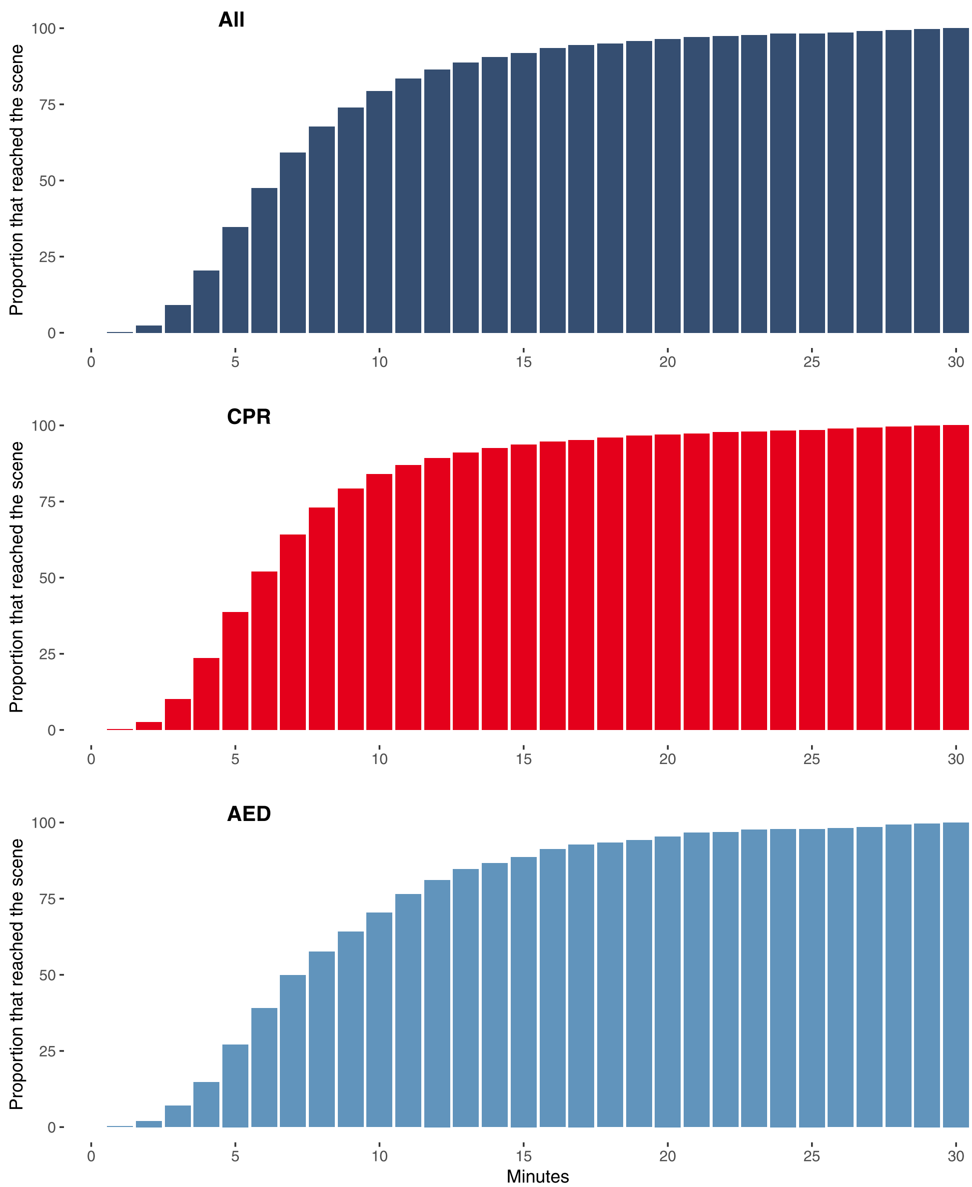

Fig. 3 – Cumulative proportion of lay responders reaching the scene of the suspected OHCA, showing all cases (top), cases who run for CPR (middle) and cases who run via an AED (bottom).

Future actions

Weisfeldt et al.[25] suggested that AED programs/education in AED usage should be aimed to for OHCAs in public locations (due to a low rate of ventricular fibrillation residential settings), while bystander CPR is preferable in residential settings. Nevertheless, to increase overall survival in OHCA we need to aim interventions at those who suffer their cardiac arrest at home, since the majority of OHCAs occur in residential areas. Programs such as Heartrunner (Swe, DK), HartslagNu (Netherlands), Good Samaritan (UK) and Pulse Point (US) have the potential to organize the logistics, and alert resident neighbours with CPR knowledge. If AEDs are placed in residential areas with availability 24/7, preferably in outdoor cabinets and in well-known locations such as a local food/convenience store or a school, it should be possible to reach the OHCA victim at home before the VF deteriorates into an asystole.

Strengths and limitations

The strength in this paper is that we were able to measure both distance and speed with actual coordinates of lay responders participating in a real-life setting. The estimates of travelling speeds do not rely on assumptions of which way the responder chose to travel (e.g. shortest path).

This paper has several limitations. We do not know how the lay responders travelled. It is quite possible that some lay responders travelled by bicycles and cars, thus, the speed may represent an overestimate of a responder travelling by foot. However, this setting reflects real-life, where future lay responders most probably will choose different ways of transport.

The results should be interpreted as the time it takes to reach the buffer zone. If the patient and/or the AED are in a large/high rise building, the time to reach the patient is probably longer than in the current study.

Table 2 – Description of lay responders reaching the scene.

	All	CPR	AED
n	2176	1430	746
Age (median [IQR])	37 [29, 45]	37 [29, 45]	37 [29, 46]
Male sex (%)	1113 (51.4)	713 (50.0)	400 (54.1)
Access to AED (%)	603 (27.9)	330 (23.2)	273 (36.9)
Occupation (%)			
Fire fighter/police/security	166 (8.1)	105 (7.8)	61 (8.7)
HealthWorker	643 (31.6)	473 (35.4)	170 (24.3)
Other	1059 (52.0)	655 (49.0)	404 (57.8)
Student	169 (8.3)	105 (7.8)	64 (9.2)
Region of residence (%)			
Other	54 (2.5)	37 (2.6)	17 (2.3)
Region Västra Götaland	620 (28.7)	418 (29.4)	202 (27.4)
Region Stockholm	1487 (68.8)	968 (68.0)	519 (70.3)

To measure travelling speed, two necessary conditions are to have a starting point and a destination. We were not able to measure the travelling speed among those who did not reach the scene. It is possible that they may be different compared to those who reached the scene. We cannot exclude the possibility that they travelled at a slower pace.

Another limitation is that the distance calculation for an individual is based on small distances of straight lines between the coordinates along the road. This implies that the calculation "cuts corners" and may therefore result in an overestimation of the travelling speed.

Conclusion

We found that the estimated traveling speed of a responder was 2.3 m/s or 5.14 mph among all volunteers and 1.8 m/s or 4.03 mph in areas with high population density. Lay responders who run directly to start CPR has a shorter response time compared to those who run to fetch and bring an AED, due to the shorter distance they need to travel.

Declaration of conflicts of interest

Martin Jonsson, Ellinor Berglund, Therese Djärv, Sune Forsberg, Anette Nord and Hanno L. Tan: None.

Per Nordberg, Andreas Claesson and Mattias Ringh are shareholders in Heartrunner Sweden AB.

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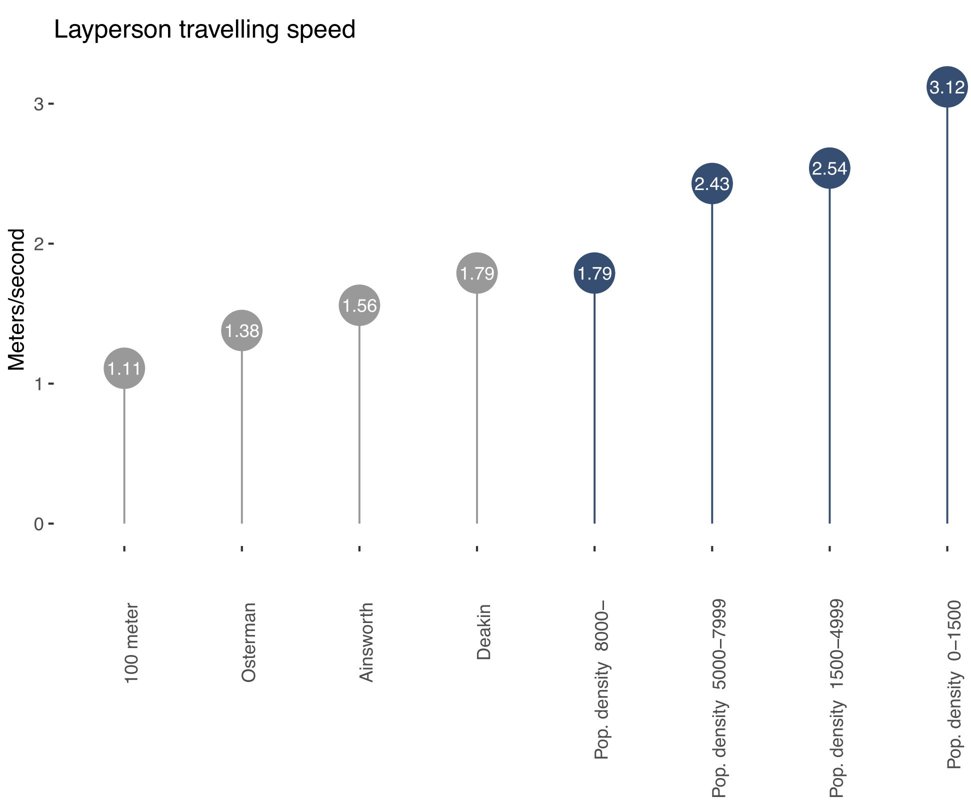

Fig. 4 – Travelling speeds compared to previously used estimates.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.resuscitation.2020.01.043.

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