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Original Article

Seasonal variation in bystander efforts and survival after out-of-hospital cardiac arrest

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Abstract

Background: This study investigated the hypothesis that out-of-hospital cardiac arrest (OHCA) incidence, public automated external defibrillator (PAD) utilization and outcome vary by season, with increased incidence and lower survival rates expected in winter. The aim was to provide insights that might optimize resuscitation efforts throughout the year.

Methods: Cases of OHCA from 2016 to 2021 were included from the Danish Cardiac Arrest Registry. Cases were stratified by season and month and analysed for frequency, witnessed status, location, bystander cardiopulmonary resuscitation (CPR), bystander PAD defibrillation and 30-day survival. The primary outcome was incidence of OHCA and variability in utilization of PADs by season. Secondary outcome was 30-day survival rates. Categorical variables were compared using Chi-square and multivariable analyses were conducted using Poisson regression.

Results: A total of 25,248 OHCA cases were included with a median age of 74 years [IQR 63–82] and 64% were male. Multivariable analyses revealed a lower incident rate ratio (IRR) of OHCA for most months (IRR 0.78 to 0.92 with 95%CI 0.72–0.98, all p-values < 0.05), except March and December, using January as reference. Seasonal rates of bystander CPR (78.4%–79.4%, p = 0.414) and PAD shock (8.9%–9.8%, p = 0.266) remained consistent throughout the year. The proportion of residential OHCAs were higher during winter than in summer (79.4% vs 77.5%, respectively, p = 0.023). Crude 30-day survival rates showed significant seasonal variation with lower survival rates during winter (11.1%) compared to spring (12.4%), summer (13.4%) and fall (12.2%, p = 0.001). However, after adjusting for factors such as sex, comorbidities, and OHCA circumstances (witnessed status, bystander CPR, PAD shock), no significant seasonal variation in survival remained (all p > 0.05).

Conclusion: Incidence of OHCA was higher in winter, but rates of bystander CPR and PAD shock remained consistent across seasons. Crude mortality rates were significantly lower during winter. However, multivariable regression analysis revealed no significant variation in survival rates by month.

Keywords: Out-of-hospital cardiac arrest, Public defibrillator, Bystander, Seasons, Weather, Survival

Introduction

Understanding how survival rates and resuscitation efforts vary across seasons can offer insights for improving outcomes in out-of-hospital cardiac arrest (OHCA) year-round. Despite advancements in resuscitation, OHCA survival and prognosis remain poor,[1,2] underscoring the need to explore factors that may influence these outcomes, including potential seasonal variation.

Current literature provides valuable insights into the epidemiology of OHCA and the importance of factors such as bystander cardiopulmonary resuscitation (CPR) and the use of public automated external defibrillators (PADs).[3,4] Studies from North America have reported an increase in OHCA incidence and mortality during winter.[5–7] Moreover, lower rates of bystander-performed defibrillation have been observed during winter months, particularly in outdoor cases.[5] Similar associations between lower temperature and OHCA incidence and outcome have been observed in Japan and China.[8–10] However, the results are inconsistent, as another study found no association between season and OHCA in North America.[11]

The relationship between OHCA and season is less explored in temperate European settings with more moderate climate variations throughout the year. However, an association between general mortality and cold weather has been reported.[12] Denmark, with is milder

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seasonal shifts, high rates of bystander resuscitation, and well-validated national registry data,[13] provides a unique opportunity to assess whether previously observed seasonal trends in OHCA persist in a Northern European context.

This study examines seasonal differences in OHCA incidence, bystander CPR and PAD utilization in Denmark. Our primary focus is on OHCA incidence and bystander intervention rates across seasons, with a secondary aim to assess whether survival rates are affected by seasonal variation. If seasonal disparities are observed, potential public health interventions could include targeted public awareness campaigns addressing winter-related health risks and behaviour or focused bystander CPR training during colder months.

Methods

Study setting

This study employs a registry-based approach, utilizing data collected from Danish Cardiac Arrest Registry[13] linked with data from the Danish National Patient Register.[14] In Denmark, each individual is assigned a unique identifier upon birth or immigration, the Civil Registration Number, allowing the linkage of data on pre-hospital event, subsequent hospitalization, discharge records and vital status.[15] Data was collected from all registered OHCAs in Denmark from January 1st, 2016 to December 31st, 2021.

Denmark provides tax-funded access to healthcare for all citizens year-round, with 24/7 emergency services accessible via emergency calls to dispatch centres. Emergency medical services (EMS) are dispatched according to the assessed urgency of each call.[16] If resuscitation has been attempted (either by bystanders or EMS), the EMS personnel are obligated to fill out a case report form about the OHCA in the patient medical record. This form is nationally implemented and since 2016 the registration has transitioned to an integrated component of the electronic pre-hospital patient chart. Subsequently the entire pre-hospital patient chart for each cardiac arrest report undergoes manual validations and text string searches to optimize data capture and quality assurance.[17] In Denmark, EMS personnel are mandated to initiate resuscitation unless injuries incompatible with life are present.

Study population

During the study period, approximately 5,000 OHCAs were registered annually, corresponding to an incidence rate of approximately 86 per 100,000 individuals per year.[1] To ensure the independency of each observation, only the first occurrence of OHCA per individual was included, excluding any subsequent events in the same patient. Furthermore, the scope of this study was confined to adult cases, including individuals ages 18 years and above. Thus, all patients younger than 18 years were excluded. Given the central focus on bystander resuscitation and the utilization of PADs prior to EMS arrival, cases witnessed by EMS were excluded. When assessing survival, cases without a valid civil registration number were excluded as this is identifier is essential for linking pre-hospital events, hospitalizations and vital status.

Co-morbidity

In this study, cardiac co-morbidity was defined as the presence of pre-existing angina pectoris, ischaemic heart disease, heart failure or acute myocardial infarction. Non-cardiac diagnoses included in this study were chronic obstructive pulmonary disease (COPD) and diabetes. These diagnoses were included, as previous studies have identified them as the most common co-morbidities among OHCA cohorts and associations between the diagnoses and OHCA outcome has been demonstrated.[18–20] The diagnoses were identified through linkage of the study cohort and data from the Danish National Patient Register. A full list of included ICD-10 codes is provided in Supplementary Table S1. Diagnoses registered a maximum of five years before the index OHCA event were included. Furthermore, the study population was stratified by number of co-morbidities into groups: 0; 1; 2; 3; and 4 or more.

Statistical methods

For descriptive analyses, OHCA events were stratified by season to compare baseline characteristics and pre-hospital interventions across different the year. Seasons were defined as winter (December-February), spring (March-May), summer (June-August), and fall (September-November). Additionally, event location (residential vs public) was used as a stratification variable when analyzing raw event counts. Seasonal stratification was chosen to consolidate case numbers and simplify interpretation. Categorical variables were compared using chi-square tests.

To assess the association between month and OHCA incidence, bystander interventions and survival, regression models were performed and included month as an independent variable. Month was chosen over season to achieve higher temporal resolution when assessing incidence and survival variations. A Poisson regression model was used to estimate the incidence rate ratio (IRR) of OHCA by month, using January as the reference month. Independent variables included in this model were month, year of OHCA, sex and the listed co-morbidities. This model was applied separately for each location type (residential and public). A separate Poisson regression model examined the association between 30-day survival and month, adjusting for, sex, co-morbidities, witnessed status, bystander CPR, bystander defibrillation and location. An offset term (the logarithm of total OHCA cases per month) was included in the model to account for the total number of cases and to model survival rates rather than absolute numbers. To analyse the impact of each independent variable in the regression model, analysis of variance type III was used.

For all statistical analyses, cases with missing data either in the exposure or outcome variable were excluded when assessing associations. No imputation were performed. Statistical significance was defined as a p-value < 0.05. All IRR are presented with their corresponding 95% confidence intervals (CI). The entirety of these analyses was performed using R studio version 4.4.1[14] with attached packages.[21–28]

Ethics

In Denmark, ethical approval and individual patient consent are not required for registry-based studies. Permission to access and use the data for research purposes was granted by the data-responsible institute in the Capitol of Region Denmark, in compliance with the Data Protection Act and the General Data Protection Regulation.

Results

The total number of OHCAs from 2016 to 2021 in Denmark was 30,196. Of these, 25,248 were included in the study. The selection of the study sample is shown in Fig. 1.

Approximately 64.0% were male and the median age was 74 years [IQR 63–82]. Nearly half of all cases were witnessed by bystanders (49.5%) with 78.8% receiving bystander CPR and 9.4% receiving a PAD shock. The proportion of public OHCAs was lower in winter (20.6%) compared to summer (22.5%, $p < 0.05$). There was no significant difference in percentages of witnessed OHCAs, bystander CPR or shock from a PAD across seasons. The crude 30-day survival rates were lowest in winter (11.1%) and highest in summer (13.4%, $p < 0.05$). The overall prevalence of at least one of the included co-morbidities was approximately 40% and did not vary significantly across the year. The only significant variation regarding co-morbidity was a higher prevalence of heart failure in the winter cases (17% vs 15.3%, 15.9% and 15.3% for spring, summer and fall respectively, $p < 0.05$). Neither did the number of co-morbidities per patient vary significantly. These statistics are depicted in further detail in Table 1.

Overall OHCA incidence demonstrated seasonal variation, with a marked increase during winter compared to summer and spring. Stratification according to location revealed that this variation was primarily driven by a higher number of deaths following residential OHCA in the winter months, as the number of survivors remained consistent for both residential and public OHCA cases (Fig. 2).

The Poisson regression analysis, adjusting for sex, year and month of occurrence and comorbidity, revealed no significant differences in the incidence rate ratio (IRR) of public OHCA across the months (IRR 0.87 to 1.04, all $p > 0.05$). However, for the residential OHCA, when comparing to January, all months except March and December (IRR = 0.98 [95%CI: 0.92–1.05], $p = 0.554$ and IRR = 0.96 [95%CI: 0.90–1.02], $p = 0.204$ respectively) showed a lower incidence rate ratio of OHCA, with the most distinct decreases observed in June and August (IRR = 0.78 [95%CI: 0.73–0.83], $p < 0.001$ and IRR = 0.78 [95%CI: 0.72–0.83], $p < 0.001$, respectively). These results are depicted in Fig. 3.

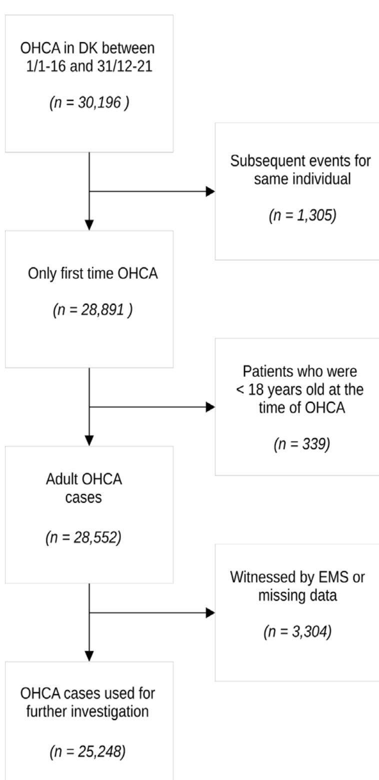

Fig. 1 – Flowchart illustrating the selection process of the study sample. OHCA; out-of-hospital cardiac arrest. DK; Denmark. EMS; emergency medical services.

Chi-square test revealed significant variation in crude survival rates across seasons with 11.1% during winter, compared to 12.4% in spring, 13.4% in summer and 12.2% in fall (p = 0.001). In the multivariable Poisson regression, only May showed a significantly increased survival IRR compared to January (IRR = 1.23 [CI: 1.03–1.46], p = 0.02). The survival rate ratios are depicted in Fig. 4. Independent variables with the greatest impact on survival included sex, heart failure, COPD, angina pectoris, witnessed status, OHCA location, bystander CPR and PAD shock, as detailed in Supplementary Table S2.

Discussion

This nationwide study indicates a higher number of OHCA cases during winter compared to other seasons in Denmark, without significant seasonal variations in bystander CPR or PAD defibrillation rates, although residential OHCAs were more frequent in winter. While unadjusted survival rates were significantly lower in winter, adjusted 30-day survival rates showed no significant seasonal variation.

The increased number of OHCA cases during winter, driven by more residential OHCAs, may result from a combination of factors, including weather-related conditions, population behavior with people spending more time indoors, and seasonal illness. Furthermore, winter is associated with a higher general mortality rate, also after acute myocardial infarction.[29,30] A similar increased incidence of OHCA has been reported during winter in previous studies.[5–8,10–11] However, only few previous studies include chronic comorbidities when analyzing OHCA incidence. The increased multivariable adjusted rate ratio of OHCA during winter in this study underscores the heightened risk during this season, even when adjusting for other factors affected by seasonality.

A previous study reported lower rates of bystander defibrillation during winter.[6] This seasonal disparity was not observed in our study, where defibrillation rates remained consistent across seasons. The consistent use of PADs in our study could reflect their high availability in Denmark,[1] where defibrillation rates reached 9% in this study compared to 1–2% reported in previous studies.[5,9] Seasonal variation in bystander CPR has not been well-documented in the literature. However, overall rates of bystander CPR in studies, investigating seasonal variation, have been reported at approximately 40%,[5,9] markedly lower than the 80% observed in our study. This could highlight the strong public engagement in resuscitation in Denmark, likely driven by national strategies such as mandatory and robust CPR training programs,[31] public awareness campaigns and dispatcher-assisted CPR.[32–37]

Our study revealed lower crude survival rates during winter, despite consistent rates of bystander CPR and PAD shock across all seasons. This discrepancy may be explained by the higher incidence of residential OHCA during winter, which has previously been linked to reduced survival rates.[38–40] However, the significant seasonal variation in survival rates disappeared in our multivariable regression analysis. This suggests that the initial variation was likely driven by underlying factors such as patient comorbidity, demo-

Table 1 – Statistics regarding the study population. Numbers are N (%) unless otherwise specified. IQR; interquartile range. CPR; cardiopulmonary resuscitation. PAD; public automated external defibrillator. AMI; acute myocardial infarction. COPD; chronic obstructive lung disease.

Variable	Winter (n = 6918)	Spring (n = 6557)	Summer (n = 5703)	Fall (n = 6070)
Age (median [IQR])*	74 [64, 83]	74 [63, 82]	73 [62, 82]	73 [63, 82]
Male	4,333 (62.6)	4,196 (64.0)	3,668 (64.3)	3,937 (64.9)
Bystander witnessed	3,355 (48.7)	3,262 (49.9)	2,872 (50.5)	2,965 (48.9)
Public location*	1,423 (20.6)	1,360 (20.8)	1,277 (22.5)	1,339 (22.1)
Bystander CPR	5,460 (79.1)	5,133 (78.4)	4,521 (79.4)	4,753 (78.4)
PAD shock	631 (9.2)	579 (8.9)	548 (9.7)	590 (9.8)
30-day survival*	767 (11.1)	810 (12.4)	762 (13.4)	738 (12.2)
AMI	314 (4.5)	297 (4.5)	266 (4.7)	257 (4.2)
Angina Pectoris	424 (6.1)	394 (6.0)	313 (5.5)	320 (5.3)
COPD	1,415 (20.5)	1,241 (18.9)	1,087 (19.1)	1,186 (19.5)
Diabetes	950 (13.7)	920 (14.0)	764 (13.4)	859 (14.2)
Heart failure*	1,179 (17.0)	1,001 (15.3)	905 (15.9)	929 (15.3)
Ischemic heart disease	841 (12.2)	777 (11.8)	648 (11.4)	668 (11.0)
0 Comorbidities	4,041 (58.4)	3,963 (60.4)	3,443 (60.4)	3,638 (59.9)
1 Comorbidity	1,535 (22.2)	1,375 (21.0)	1,219 (21.4)	1,336 (22.0)
2 Comorbidities	746 (10.8)	658 (10.0)	587 (10.3)	611 (10.1)
3 Comorbidities	365 (5.3)	369 (5.6)	274 (4.8)	332 (5.5)
4 or more comorbidities	231 (3.3)	192 (2.9)	180 (3.2)	153 (2.5)

* indicates significance level of $p < 0.05$.

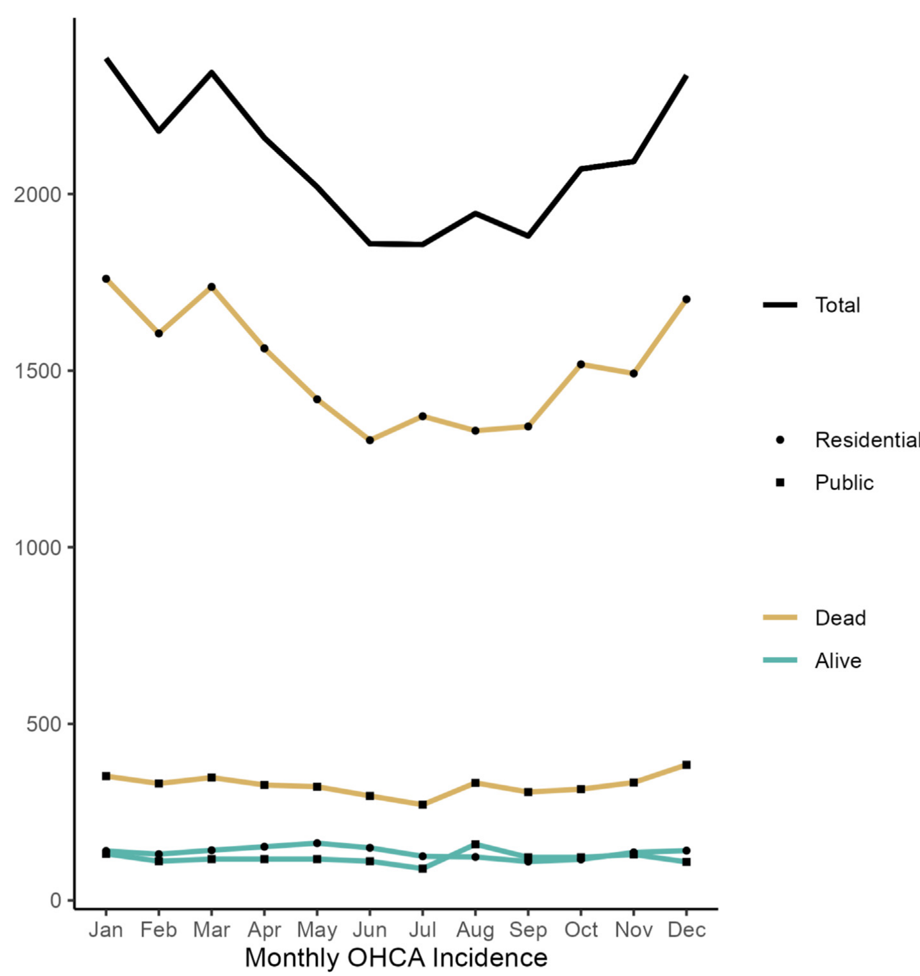

Fig. 2 – Crude incidence of OHCA shown according to month, location and 30-day survival. The black line indicates total of all OHCA. Lines are coloured according to survival status and the shapes indicate location type.

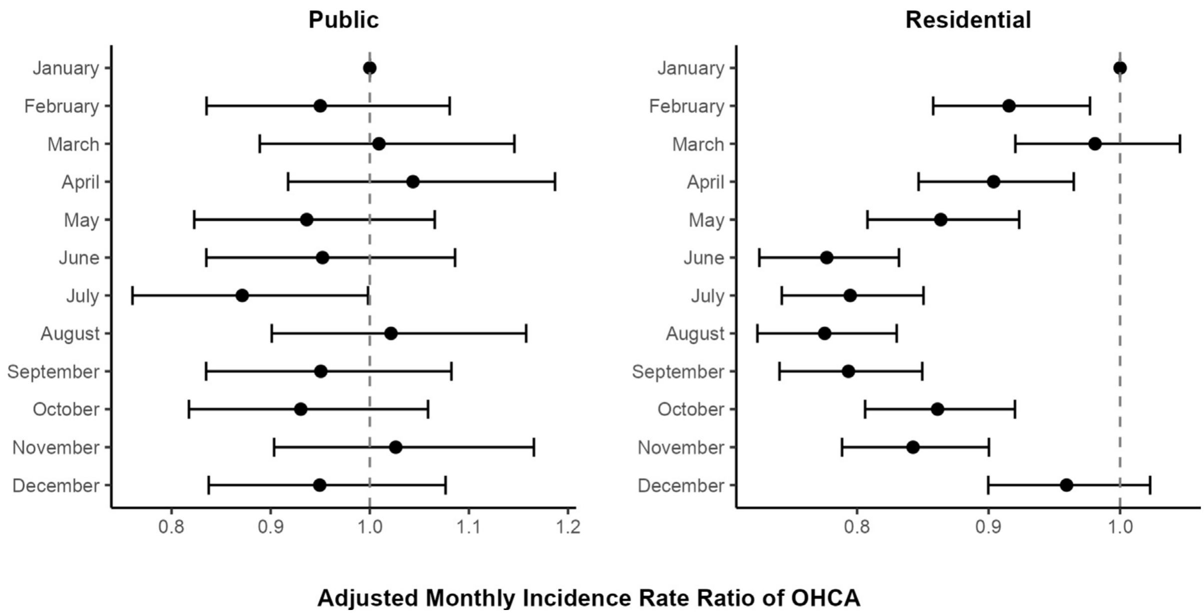

Fig. 3 – Forest plot showing the adjusted monthly rate ratio of OHCA incidence using January as reference month. Adjusted for year of OHCA, sex and co-morbidities.

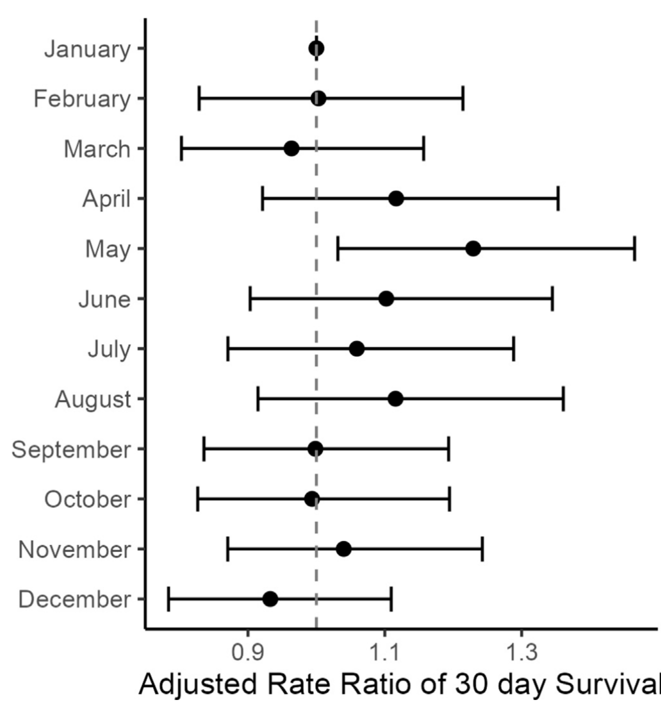

Fig. 4 – Forest plot showing the adjusted monthly rate ratio of 30-day survival following OHCA using January as reference month. Adjusted for sex, co-morbidities, witnessed status, bystander CPR, bystander defibrillation and location type.

graphic characteristics and interventions like CPR and defibrillation rather than a seasonal effect alone. While these factors did not show significant individual seasonal variation, their combined effect have significant impact on survival rates.

In this study, we found no significant seasonal variation in the prevalence of pre-existing comorbidity among OHCA patients. This could indicate that the increased winter OHCA incidence is not due to higher baseline illness severity among OHCA patients in winter compared to other seasons. This suggests that other factors than individual chronic health conditions may contribute to seasonal disparities in OHCA incidence. Although chronic conditions were assessed, many acute illnesses, which are known to vary seasonally, were beyond the scope of this study. These factors, such as respiratory infections could contribute to the observed seasonal disparities in OHCA incidence. Furthermore, the incidence of OHCA in the Danish Cardiac Arrest Registry depends on initiation of resuscitation, and it could be that in winter, resuscitation is initiated in a higher number of cases, however unlikely.

In a seasonal context, survival after cardiac arrest is influenced by several factors, which, in this study, cannot be pinpointed individually. Our findings highlight the importance of considering seasonal variation regarding OHCA incidence, but also indicate that the resuscitation efforts along with outcome are not affected by seasonal variations. Future research could investigate the underlying mechanisms driving seasonal trends in OHCA incidence to possibly identify high-risk patients with the aim of preventing OHCA, especially during winter, where an increased number of events are seen.

Limitations and strengths

This study has some limitations. First, we did not examine any link between acute seasonal concurrent disease or short-term medical consultations, which could contribute to the seasonal variation in OHCA incidence. Secondly, information on cases where a PAD was applied but did not recommend a shock is unavailable, leaving any seasonal variation in PAD application unknown.

However, this study is a nationwide, population based analysis utilizing a validated OHCA registry with high-quality data, ensuring comprehensive case capture and complete follow-up across Denmark.

Conclusion

This study highlights the seasonal variation in OHCA incidence, with a notable increase during the winter months. Despite this, the rates of bystander CPR, PAD defibrillation and underlying co-morbidities remained consistent across seasons. Adjusted multivariable analysis, revealed no significant seasonal variation in survival, suggesting that other factors such as acute disease pattern, age and comorbidities drive the crude differences in survival outcomes observed in this study.

CRediT authorship contribution statement

Niels Saaby Hald: Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Harman Yonis:** Writing – review & editing, Methodology, Conceptualization. **Mathias Hindborg:** Writing – review & editing, Methodology, Conceptualization. **Helle Collatz Christensen:** Writing – review & editing, Methodology, Conceptualization. **Jannie Kristine Bang Gram:** Writing – review & editing, Methodology, Conceptualization. **Erika Frischknecht Christensen:** Writing – review & editing, Methodology, Conceptualization. **Fredrik Folke:** Writing – review & editing, Methodology, Conceptualization. **Gunnar Gislason:** Writing – review & editing, Visualization, Supervision, Methodology, Conceptualization. **Christian Torp-Pedersen:** Writing – review & editing, Visualization, Supervision, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Kristian Bundgaard Ringgren:** Writing – review & editing, Visualization, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Harman Yonis reports a relationship with TrygFonden that includes: funding grants. Harman Yonis reports a relationship with Laerdal Medical AS that includes: funding grants. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resplu.2025.100934.

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