This is an Accepted Manuscript for Epidemiology & Infection. Subject to change during the editing and production process.

DOI: 10.1017/S0950268824001870

Second reported outbreak of pneumococcal pneumonia among shipyard employees in Turku, Finland, August – October 2023: a case-control study

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Word count: 4149

Summary: In August 2023, the Finnish Institute for Health and Welfare received reports of a potential cluster of pneumococcal pneumonia cases among shipyard employees in Turku, Finland. Considering a similar outbreak in the same shipyard in 2019, we initiated a case-control study to investigate individual and environmental risk factors specific to this occupational setting in order to inform targeted prevention measures. In total, 14 hospitalized cases were identified from 19 August to 15 October 2023. *Streptococcus pneumoniae* serotypes 4 and 9V were isolated from blood cultures of seven cases. Eleven cases and 67 controls working at the shipyard were included in the case-control study. Compared with controls, cases were more likely to be living in an apartment/studio or a hotel/hostel, and less likely in a house or with family. Furthermore, cases were more likely to have a shorter duration of employment (< 1 year) at the shipyard compared to controls. Control measures, including an information and a vaccination campaign, were implemented. We emphasize shipyard-wide hygiene improvements and recommend nationwide consideration of expanding pneumococcal vaccination eligibility to all shipyard construction employees as an occupational high-risk group.

https://doi.org/10.1017/S0950268824001870 Published online by Cambridge University Press

BACKGROUND

Streptococcus pneumoniae is a Gram-positive bacterium transmitted from person to person through direct contact with respiratory secretions. *S. pneumoniae* infection can lead to pneumococcal disease (PD), presenting with symptoms that vary from mild conditions like otitis media and sinusitis to more severe illnesses such as pneumonia. In certain cases, the infection may progress to an invasive form or cause life-threatening complications. Around 5% of pneumococcal pneumonia infections are fatal. The bacteria can also colonize the respiratory tract of healthy people, predominantly children, without causing illness, resulting in a state known as carriage [1].

Some groups are at increased risk for getting PD, including children under 5 and adults over 65-years-old. Other risk factors for severe and invasive infections include alcoholism, smoking, and absence or dysfunction of spleen [1]. Furthermore, increased occurrence of pneumococcal pneumonia and invasive pneumococcal disease (IPD) has been reported among welders and professionals exposed to welding fumes or other dusts and fumes [2,3].

One of the known effective measures of protection against PD is vaccination. There are two types of vaccines against PD. Pneumococcal conjugate vaccines induce immunological memory and provide protection against mucosal pneumococcal infections and carriage, varying in the number of serotypes they cover. The pneumococcal polysaccharide vaccine (PPV23) does not induce immunological memory and is ineffective against carriage, but it offers protection against the largest number of serotypes [4].

Most countries of the European Union/European Economic Area (EU/EEA) have introduced pneumococcal vaccines for infants and children into their National Immunization Programmes and many also offer the vaccines for adult risk groups in the case of known medical risk groups or elderly persons [5]. Nevertheless, limited recommendations exist for known occupational risk groups such as welders and industrial construction workers, and even fewer refer to the shipyard setting, even though over the last decade several outbreaks have been reported among shipyard employees in European countries. Such events have been observed in France in 2020, Norway in 2019, and in Northern Ireland in 2015 [6–9]. Most notably, in 2019, there was also an outbreak of PD in the same Finnish shipyard in Turku as we report here [10].

https://doi.org/10.1017/S0950268824001870 Published online by Cambridge University Press

In this article we describe the second reported outbreak taking place in Turku shipyard within five years and the analytical case-control study that we performed with the intent of identifying setting-specific risk factors to further inform control measures and formulate targeted recommendations for prevention of future outbreaks. As far as the authors are aware, this is only the second analytical study performed in for a pneumococcal outbreak in a shipyard setting as the remaining reported shipyard outbreaks were case series studies [6–10].

METHODS

Outbreak detection

On 29 August 2023, the Finnish Institute for Health and Welfare (THL) was notified by the Wellbeing Services County of Southwest Finland (Varha), of a potential cluster of pneumococcal pneumonia among employees from a shipyard in Turku, Western Finland. As of 14 October 2023, 14 cases of pneumococcal pneumonia had been identified, all were employed at Turku shipyard. We investigated the outbreak and performed a retrospective case-control study among the shipyard's employees. The outbreak investigation team consisted of experts from THL, Varha, Turku Shipyard, and the Finnish Institute of Occupational Health (FIOH).

Setting

At Turku shipyard, at any time, there are between 6 000 – 10 000 employees working on site. Some are long-term/permanent staff, while others have a short-term contract. The shipyard workforce is divided into those employed by the main company (around 2 000 persons) and those employed by the many different subcontractors, which number between 500 - 800.

Shipyard work is organized into four main sectors: the wet dock, the dry dock, outfitting of building blocks in building halls, and hull production in building halls. At the time of the outbreak, there was one ship in the final stages of shipbuilding being outfitted in the wet dock, and one ship under construction in the dry dock. Nevertheless, various construction work was being carried out simultaneously in all four sectors of the shipyard.

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Case and control definitions

For the case-control study, we defined a probable case as an individual with a clinical presentation consistent with pneumococcal pneumonia or IPD, who was working in Turku Shipyard, and was diagnosed after 1 August 2023. A confirmed case was an individual who fulfilled the criteria for a probable case and *S. pneumoniae* was isolated from blood or cerebrospinal fluid or *S. pneumoniae* antigen was detected in urine.

A control was an individual who had worked at Turku Shipyard at least since 1 August 2023 and did not fulfil the criteria of a probable or confirmed case. We excluded individuals who worked exclusively in an office setting.

Data collection

1. *Questionnaire design*

We designed a questionnaire covering demographics, type of accommodation, living situation, occupation details (tasks, sector of work, length of employment), working patterns (duration of work), working in proximity to others, occupational exposures (welding, exposure to respiratory irritants), use of protective equipment, behavioural and health risk factors for PD (consumption of alcohol, smoking habits, comorbidities), and pneumococcal vaccination. Questionnaires were available in six languages (Finnish, English, Russian, Polish, Portuguese, and Spanish).

2. *Recruitment of study participants*

We recruited controls in-person using a convenience sampling strategy during a field visit to the shipyard on 16 November 2023. Employees working at the shipyard at least since 1 August 2023 were recruited to take part in the study. The control questionnaires were paper-based and self-administered on-site. Support on filling in the questionnaire was available.

All identified cases were invited for an interview over telephone. The interview followed an almost identical questionnaire as for the controls, differentiated by the referenced exposure period, which was limited to 3 months before illness onset for cases and the period of August – October 2023 for controls. Data collection spanned several working days in the three weeks after the field visit. The interviews were conducted in the preferred language of the respondent based on the available translations.

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Analysis

We compared cases and controls according to age, sex, nationality, and other chosen risk factors using Welch's two sample t-test or Fisher's exact test as appropriate. Furthermore, for risk factors of interest we calculated the odds ratios (OR), 95% confidence intervals (95%CI), and *p*-values using Fisher's exact test. A *p*-value of less than 5% was considered statistically significant. The analysis was performed using R software (version 4.2.1).

Clinical information

Cases hospitalized due to pneumococcal pneumonia underwent diagnostic tests at the hospital. Blood cultures and/or urine antigen tests (CerTest *S. pneumoniae* card test, one strep coloured chromatographic immunoassay, Certest Biotec, S.L., Zaragoza, Spain) were performed as well as chest x-rays.

Routine surveillance

In Finland, laboratory-confirmed cases of IPD are reported by clinical microbiology laboratories to the National Infectious Disease Register (NIDR)[11]. THL routinely performs species verification, serotyping, and whole genome sequencing (WGS) for all pneumococci isolated from blood and cerebrospinal fluid.

Microbiological investigations

Clinical outbreak isolates from blood cultures underwent serotyping by *Quellung* reaction and WGS at THL. We confirmed the serotype genomically using PneumoCaT, performed multilocus sequence typing (MLST) to determine sequence types (STs) and core and accessory genome MLST (cgMLST including 1 234 genes; aMLST including 708 genes) profiles using Ridom SeqSphere+ version 9.0.1. We performed a comparison of isolates from this outbreak to isolates from the 2019 Turku shipyard outbreak [10]. Results were visualized using minimum spanning trees. The data for this study have been deposited in the European Nucleotide Archive (ENA) at EMBL-EBI under accession numbers PRJEB35348 and PRJEB76834.

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Outbreak control measures

An information campaign and mass vaccination campaign were launched at the shipyard. Employees were vaccinated with the 13- or 20-valent pneumococcal conjugate vaccines (PCV13 or PCV20). Information about the outbreak was also communicated at an international level.

RESULTS

In total, 14 cases were identified as belonging to the outbreak, eight confirmed and six probable. The first case was confirmed on 19 August 2023 and the last case on 15 October 2023 (Figure 1). Most of the cases were male (n=13) and represented seven different nationalities: Finland (n=4), Lithuania (n=2), Poland (n=2), Russia (n=2), Ukraine (n=2), Latvia (n=1), and Romania (n=1).

Figure 1. Weekly cases of pneumococcal pneumonia among shipyard employees by date of hospital admission, Turku, Finland, August – October 2023 (n = 14).

Recruitment of study participants

During the field visit to Turku Shipyard, 82 controls were recruited. After applying the exclusion criteria, we included 67 controls.

Eleven of the 14 cases were interviewed by phone and included in the case-control study. One case declined participation and two were unreachable through the provided contact details.

Case-control analysis

Median age of the 78 study participants was 45 years, the majority of participants were male (97%), and most were Finnish (64%). There were no significant differences between cases and controls in terms of age, sex, nationality, reported alcohol consumption, smoking status, or presence of comorbidities (Table 1).

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Table 1. Characteristics of study participants, Turku, Finland, August – October 2023 (n = 78)

Seventy-six (99%) study participants reported at least occasional exposure to respiratory irritants such as dusts, fumes, and/or smoke. Seven study participants (9%) reported borrowing personal protective equipment (PPE) from co-workers at least occasionally and two cases (18%) borrowed it at least 3-4 times a week.

Fifteen per cent of the study participants reported being vaccinated in 2019 against PD. Approximately 28% of participants (16 controls and 6 cases) did not recall ever being vaccinated (either during the 2023 vaccination campaign, while working at the shipyard in general, or before) (Table 1).

Based on the univariate analysis, we identified type of accommodation, living situation, and duration of employment at the shipyard as significant factors. Compared to controls, cases were more likely to be living in an apartment/studio (OR: 10.3, 95%CI: 1.3 – 458.94) or in a hotel/hostel (OR: Inf, 95%CI: 1.2 – Inf). Cases were less likely to be living in houses (OR: 0.00, 95%CI: 0.00 – 0.46), living with family (OR: 0.15, 95%CI: 0.02 – 0.82), or to be working longer than one year at the shipyard (OR: 0.1, 95%CI: 0.0 – 0.7). No other significant factors were found (Supplementary figure S1).

Figure 2. Univariate analysis of potential risk factors for pneumococcal pneumonia among shipyard employees, Turku, Finland, August – October 2023 (n = 78). *p*-values < 0.05 were considered as significant and are highlighted in red.

Clinical findings and microbiological investigations

All identified cases were hospitalized at Turku University Hospital (TYKS). Blood samples were collected and cultured at TYKS laboratory for all 14 cases, of which 7 were positive for *S.*

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pneumoniae. Of the 14 cases, 11 were tested with urinary antigen tests, of which two were positive, one with and one without bacteraemia. X-ray imaging confirmed lobar or bilateral pneumonia in all 14 cases.

We confirmed five of the pneumococcal blood isolates as serotype 4 and two as serotype 9V. Three STs were identified: ST801 (serotype 4, n = 5), ST2025 (serotype 9V, n = 1), ST239 (serotype 9V, n = 1). The five serotype 4 isolates were genetically similar by cgMLST and aMLST with ≤ 1 allelic difference, while the two serotype 9V isolates were different, displaying 1 233 allelic differences (Figure 2).

Figure 2. Minimum spanning tree based on cgMLST and aMLST of shipyard outbreak isolates, Turku, Finland, August – October 2023

Outbreak control measures

An information campaign was launched at the end of August 2023 aimed at permanent staff, subcontractors, and their healthcare units. The campaign promoted hand washing and disinfecting, cough/sneezing etiquette, remaining at home when sick, keeping the working environment clean, use of PPE (at least FFP2 masks), and getting vaccinated as soon as possible. It also emphasized that smoking increases the risk of contracting the disease.

As a result of the collaborative effort of the main employer (Meyer Turku), Varha, THL, and the Ministry of Health, a mass pneumococcal vaccination campaign was launched on 28 September 2023. The target groups for vaccination were shipyard employees who were frequently exposed to metal fumes, and who worked in closed, poorly ventilated conditions (N = approximately 3 000).

As of 16 October, the target number of vaccinated employees was achieved. Approximately 2 000 employees were vaccinated with PCV13 and approximately 1 000 with PCV20. The type of vaccine for an additional 150 employees was unknown.

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The occurrence of the 2023 shipyard outbreak was communicated to other EU/EEA Member States through EpiPulse and the Early Warning and Response System in September 2023. However, no other countries reported cases connected with this outbreak.

Comparison of pneumococcal outbreaks at Turku shipyard, 2019 and 2023

An outbreak of PD was previously reported in 2019 at the same shipyard in Turku [10]. It lasted around 214 days with 37 reported cases, whereas the outbreak in 2023 lasted 57 days with 14 reported cases.

Comparing the case characteristics of the 2019 and 2023 PD outbreaks, we found significant differences in identified serotypes, the number of roommates (including family members), and the reported work sectors (Table 2).

Table 2. Comparison of cases reported in the 2019 and 2023 pneumococcal disease shipyard outbreaks, Turku, Finland (n = 51)

Most cases in both outbreaks were current smokers (77% in 2019 and 55% in 2023), were working mainly indoors (57% in 2019 and 82% in 2023), lived with roommates/family (75% in 2019 and 73% in 2023), and their main work task did not involve welding (86% in 2019 and 64% in 2023) (Table 2).

In both outbreaks, one of the serotypes responsible for causing illness was serotype 4, which was identified among 11 cases (30%) in 2019 and 5 (36%) in 2023. Cluster analysis of serotype 4 isolates from both outbreaks revealed that all five isolates from 2023 were clonally related to four of the isolates from 2019 with 4-8 allelic differences between them (Figure 3).

Figure 3. Minimum spanning tree based on cgMLST and aMLST of serotype 4 shipyard outbreak isolates from 2019 and 2023, Turku, Finland

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DISCUSSION

A serious pneumococcal pneumonia outbreak occurred for the second time at the same shipyard in Finland within 5 years. As far as the authors are aware, such a repeated PD outbreak has not been previously reported.

In the 2023 outbreak, most cases were male, between 39 – 51-years-old, of non-Finnish nationality, although this most likely reflects the general distribution of working population at the shipyard. In terms of working conditions, most were working mainly indoors in the wet dock sector, and welding was not among their tasks. Over half of the cases were current or previous smokers.

In the univariate case-control analysis we did not find significant associations for known pneumococcal pneumonia risk factors, such as smoking, alcohol consumption, comorbidities, or lack of vaccination. Furthermore, while welders are recognized to be at greater risk of PD, due to their exposure to metal fumes [3], being a welder, being exposed to welding fumes, or welding were also not significant in the analysis [12]. Likewise, we found no significant associations for other investigated factors such as working in proximity to others, type of work tasks performed, sectors of work, exposures to respiratory irritants, or using PPE. This is likely due to 1) the low number of cases and/or 2) cases and controls being too similar in terms of individual risk factors and environmental exposures to show any association.

Moreover, several factors associated with living conditions were significant, as well as duration of employment. This could be due to selection bias, which likely played a role during control recruitment, as recently employed workers were excluded from participation. This means that our controls could be more settled and/or have longer employment at the shipyard which in turn could influence the housing situation, living with family, employment duration, or access to occupational healthcare. To assess this, we performed a sensitivity analysis (results not shown), using the same exclusion criteria for cases as for controls (working at the shipyard at least since 1 August 2023), and using a 90% confidence interval to account for the smaller sample size. Even so, analysis of 9 cases and 67 controls revealed the same significant risk and protective factors.

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None of the cases reported living in a house and most indicated living with others (7/11), which could indicate that more crowded living conditions increase risk of illness. On the other hand, living with family (compared to living alone or with other types of roommates) was a protective factor.

Furthermore, although we hypothesized that a longer time spent working at the shipyard would increase risk of illness, healthy controls were nine times more likely to have been working at the shipyard for over a year. Although non-significant, working at the shipyard longer than 2, 3, 4, or 5 years were still potential protective factors (compared to working a shorter time). This contradicts Torén et al.'s study, which demonstrated that cumulative exposure to inorganic dusts and fumes increases the risk of IPD [13]. One possible explanation is that the pneumococcal vaccination campaign conducted in 2019, which vaccinated around 60% of the workforce with PPV23 [10], was protective for long-term workers. Additionally, those employed longer might have developed higher protective immunity due to greater colonization potential [14].

Serotype 4, ST801 was the main pneumococcal lineage responsible for this outbreak. IPD caused by serotype 4 has increased in several European countries after the COVID-19 pandemic, particularly in adults and is associated with several genotypes, including ST801 [15–19]. As serotype 4 strains continue to circulate in European countries despite the widespread use of pneumococcal conjugate vaccines, this might lead to re-emergence or outbreaks of the disease as natural immunity wanes. This is especially relevant in the case of shipyard employees, due to the migratory, international nature of this workforce. Transmission between international shipyards has been previously reported [20]. ST801 has been associated with shipyard outbreaks in Northern Ireland [8], Norway [7], and Finland [10] in the past. The genetic similarity between the 2019 and 2023 isolates in both Finnish outbreaks was striking. A higher level of diversity over such a long period of time could be expected. The reasons behind this are still unclear, but it seems that this outbreak clone has found a specific population in which it can survive and spread [20].

The timing of the 2019 Finnish outbreak was comparable to the one reported here (cases reported late summer/beginning of autumn) [10]. In 2019 only wet dock workers, working on the final stages of the ship construction in the outfitting quay, were affected. However, in 2023, three cases reported working only at the dry dock, indicating that the risk of infection is not restricted to wet dock work like previously assumed [10]. The wide range of tasks performed by affected workers in both outbreaks

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indicate that the shipyard environment and working conditions augment the risk of exposure to *S. pneumoniae*, development of PD, and can affect all shipyard employees.

Vaccination campaigns were conducted during both outbreaks, however, in 2023 it was introduced around four months sooner than in 2019. This was in large part due to lessons learned from the previous outbreak and the collaboration between different stakeholders on vaccine procurement. After the start of the vaccination campaign in October 2023 only one additional case was detected. Some of the study participants reported being vaccinated in 2019 (~15%), presumably during the previous campaign with the PPV23 vaccine. We can assume, that due to difficulties with recall, this number could be higher. Unfortunately, unless shipyard employees are permanent residents of Finland, there is no straightforward way to verify their vaccination status. Nevertheless, both the lesser magnitude of this outbreak and the prior vaccination of some of the study participants, indicate to us the potential mitigating effect that both vaccination campaigns had on the 2023 outbreak.

In Finland, it is the employer's task, in cooperation with occupational healthcare, to assess work-related health risks and offer employees the vaccinations required to be protected against work-related infections. Having many foreign subcontractors, as in the case of this shipyard, makes overseeing their adherence to vaccinating employees against PD challenging. After the outbreak in 2019, the occupational healthcare guidance given by the shipyard included a recommendation to offer pneumococcal conjugate vaccination to all new shipyard employees. However, there was no follow-up after this recommendation and the general vaccination coverage in the shipyard population is unknown.

After a similar shipyard outbreak that occurred in Norway in 2019 [7] the Norwegian pneumococcal vaccination recommendation was changed from considering vaccination for "metal welders" to "metal welders and other workers exposed to metal fumes" (Berild JD, personal communication, 7 May 2024). Since 2014, the United Kingdom National Health Service guidelines also specifically mention that welders and metal workers exposed to metal fumes are eligible to receive the vaccine [21,22]. Similar recommendations are also in place in Germany and Austria [23,24]. However, such an official, national strategy, targeted specifically against occupational PD is not currently in place in Finland, although a recommendation to vaccinate shipyard workers exposed to metal vapours has been put forward in the context of this outbreak [25].

The limitations of our study must be stressed, such as the small sample size, resulting in a possible underrepresentation of certain groups of employees, as well as random error. The specific population, setting, and continuous operations were challenging factors in this outbreak investigation, in terms of planning the recruitment of controls and questionnaire design. Based on these factors as well as limited human resources, we chose to recruit cases and controls using different methods.

The small number of cases also resulted in a low power of our analysis and a multivariable analysis for multiple risk factors was not performed. It is important to note that, as the controls were chosen through convenience sampling, there could be sampling bias and the results cannot be said to be representative of the target population of Turku shipyard workers.

We aimed to minimize recall bias and risk of misclassification by limiting the referenced exposure period. Furthermore, we also minimized selection bias arising from the language barriers by offering questionnaires in 6 languages, five of which were among the top 10 languages spoken at the shipyard.

Due to the self-reported nature of the data, the results should be interpreted with caution.

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, our case-control analysis delved into established risk factors contributing to PD susceptibility. Among others, exposure to respiratory irritants, smoking, working and living in crowded environments, poor usage of PPE, and vaccination status were considered. Apart from accommodation-related factors and length of time spent working at the shipyard, none demonstrated a high enough risk to be significantly associated with illness in our investigation, but this is most likely due to the low power of the analysis. Also, the analytical study limitations must be recognized in this instance as any inference is limited.

Multiple serotypes/lineages were identified, however most serotyped cases belonged to serotype 4 ST801, which has been previously associated with shipyard outbreaks [7,8,10]. The multiple-serotype scenario suggests that the conditions at the shipyard could be facilitating transmission and progression from carriage to severe disease in multiple independent events.

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We hypothesize that the quick and decisive implementation of a vaccination campaign led to a faster end to the outbreak, indicating the importance of this preventive measure. There is a need for clearer national guidelines for employers' obligations to offer such vaccinations to their shipyard employees, especially in the case of immigrant workers and for those companies that are based abroad. Furthermore, when developing a national strategy, consideration could be given to expanding pneumococcal vaccination eligibility to all shipyard construction workers, instead of only targeting risk groups such as welders and wet dock workers. It should also be noted that "new" employees could be especially at risk, further highlighting the need for clear vaccination guidelines in the context of an ever-changing workforce.

Our current recommendations for the shipyard would be to emphasize hygiene improvements and stress the importance of not sharing PPE between workers. Disinfectant could be made available in the workplace, ventilation improved, and information campaigns targeting good hygiene practices are indicated. Anti-smoking campaigns could be conducted to reduce smoking and exposure to tobacco. Seeing as the two outbreaks in Turku started in summer months, promotion of pneumococcal vaccination (and emphasizing the employers' responsibility to offer it) among shipyard employees in the summer could aid prevention of future outbreaks in this setting. Furthermore, to facilitate similar investigations in the future and obtain results representative of the population, we recommend looking into legal possibilities of accessing the shipyard register of employees for epidemiological studies in outbreak investigations and improving the register at shipyard level to have contact details of each worker.

Future efforts could look into performing carriage studies to gain further insight into the prevalence and serotype distribution of pneumococcal carriage in shipyard employees compared to the general at-risk population. We also recommend that additional epidemiological studies be conducted to enhance our understanding of the risk factors associated with illness in a shipyard environment. Furthermore, there is a need for a comprehensive investigation into vaccination coverage, hesitancy, and/or access barriers within the shipyard population in order to aid future endeavours to maintain high vaccination coverage in this population.

Shipyards generally have a highly international workforce, and with many different contractors moving from one shipyard to another depending on where their skills are needed. The mobility of the shipyard

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workforce underlines the importance of communication with other countries about shipyard outbreaks. To ensure a prompt response in any future outbreaks in the same setting, we propose the development of a comprehensive international outbreak protocol that can be readily implemented in the EU/EEA context. Collaboration on outbreak response efforts across EU Member States could be highly beneficial, allowing for the pooling of data and increased study power. We would also like to extend our protocol and questionnaire for consideration and utilisation in future studies (Supplementary material S2, S3, and S4).

Supplementary material

The supplementary material for this article can be found in the Supplementary materials tab.

Data availability statement

Data are available on reasonable request to the authors. Restrictions may apply to the availability of personal data linked to patient and study participant information.

The study protocol and questionnaire have been made available as supplementary material to this article (Supplement S2, S3, and S4).

The sequence data for this study are available in the European Nucleotide Archive (ENA) at EMBL-EBI under accession number PRJEB35348 and PRJEB76834.

Acknowledgements

We thank all the respondents who generously dedicated their time and effort to respond to our questionnaires.

We extend gratitude to the ECDC EPIET/EUPHEM Fellowship frontline coordinators Barbara Schimmer and Aura Georgina Aguirre-Beltran for their guidance, input, and continuous support and encouragement. We also thank Outi Lyytikäinen for reviewing the manuscript and giving valuable feedback on the structure and content.

https://doi.org/10.1017/S0950268824001870 Published online by Cambridge University Press

We acknowledge CSC – IT Center for Science, Finland, for computational resources.

Author contributions

WK, ACGP, JSN, LS, TD, MK, MF, ML, HKa, IL, HF were part of the Finnish outbreak investigation team. WK coordinated the activities related to the case-control study at national level. LS and TD were supervisors of the study. WK, ACGP, JSN, LS, TD, MK, MF, ML, HKa, IL, HF, OH, SJ contributed to the study planning and questionnaire design, including translations. WK, ACGP, JSN, LS, SJ, MK, MF, and HKa conducted interviews and recruited controls. WK, ACGP, JSN, LS, and TD were responsible for data input. WK analysed and interpreted the data. LS led the microbiological analysis. WK coordinated, drafted, and finalized the manuscript. All authors and collaborators contributed to the manuscript and approved the final version.

Competing interest

WK, ACGP, and JSN are fellows of the ECDC Fellowship Programme, supported financially by the European Centre for Disease Prevention and Control. The views and opinions expressed herein do not state or reflect those of ECDC. ECDC is not responsible for the data and information collation and analysis and cannot be held liable for conclusions or opinions drawn.

Ethical statement

This work falls within the responsibilities of THL according to the Communicable Diseases Act 1227/2016 and ethical committee clearance was therefore not required. The investigation and protocol have been approved by the Head of Department of Health Security at THL.

Funding statement

This work received no specific grant from any funding agency, commercial or not-for-profit sectors.

https://doi.org/10.1017/S0950268824001870 Published online by Cambridge University Press

Use of artificial intelligence tools

None declared.

https://doi.org/10.1017/S0950268824001870 Published online by Cambridge University Press

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TABELS

Table 1. Characteristics of study participants, Turku, Finland, August – October 2023 (n = 78)

Characteristic	Cases, N = 11[a]	Controls, N = 67[a]	*p*-value
Age	42 (39, 51)	45 (35, 50)	>0.9[b]
Unknown	0	2	
Sex			>0.9[c]
Female	0 (0%)	2 (3.0%)	
Male	11 (100%)	64 (97%)	
Unknown	0	1	
Nationality			0.076[d]
Finland	4 (36%)	46 (69%)	
Other EU/EEA country	5 (45%)	13 (19%)	
Non-EU/EEA country	2 (18%)	8 (12%)	
Living situation			0.007[d]
Alone	4 (36%)	11 (16%)	
With colleagues	4 (36%)	13 (19%)	
With family	1 (9.1%)	40 (60%)	
With (other) roommates	2 (18%)	3 (4.5%)	
Exposure to fumes	10 (91%)	63 (95%)	0.5[c]
Unknown	0	1	
Exposure to dust	11 (100%)	64 (97%)	>0.9[c]
Unknown	0	1	
Exposure to smoke	7 (70%)	50 (78%)	0.7[c]
Unknown	1	3	
Borrowing PPE			0.025[d]
Never	9 (82%)	60 (92%)	
Only occasionally	0 (0%)	5 (7.7%)	
Once or twice a week	0 (0%)	0 (0%)	

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Characteristic	Cases, N = 11[a]	Controls, N = 67[a]	*p*-value
3-4 times a week	1 (9.1%)	0 (0%)	
Every day	1 (9.1%)	0 (0%)	
Unknown	0	2	
Alcohol consumption			0.10[d]
Never	2 (18%)	13 (19%)	
Less than once a month	1 (9.1%)	14 (21%)	
Once a month	2 (18%)	5 (7.5%)	
2-3 times a month	1 (9.1%)	13 (19%)	
Once a week	4 (36%)	12 (18%)	
2-3 times a week	0 (0%)	10 (15%)	
Daily or almost daily	1 (9.1%)	0 (0%)	
Smoking status			0.13[d]
Non-smoker	4 (36%)	27 (41%)	
Former smoker	1 (9.1%)	21 (32%)	
Current smoker	6 (55%)	18 (27%)	
Unknown	0	1	
Comorbidities	3 (27%)	13 (22%)	0.7[c]
Unknown	0	9	
Vaccination against PD during 2023 campaign	5 (45%)	39 (59%)	0.5[c]
Unknown	0	1	
Vaccination against PD before 2023 outbreak	3 (27%)	25 (45%)	0.3[c]
Unknown	0	11	
Vaccination against PD in 2019	3 (27%)	9 (15%)	0.4[c]
Unknown	0	6	
Ever vaccinated against PD	5 (45%)	46 (74%)	0.077[c]
Unknown	0	5	

EU/EEA: European Union/European Economic Area

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Characteristic	Cases, N = 11[a]	Controls, N = 67[a]	*p*-value

PD: pneumococcal disease

PPE: personal protective equipment

[a]Median (IQR); n (%)

[b]Welch Two Sample t-test

[c]Fisher's exact test

[d]Fisher's Exact Test for Count Data with simulated p-value (based on 2000 replicates)

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Table 2. Comparison of cases reported in the 2019 and 2023 pneumococcal disease shipyard outbreaks, Turku, Finland (n = 51)

Characteristic	2019, N = 37[a]	2023, N = 14[a]	*p*-value
Age	48 (37, 55)	42 (39, 50)	0.5[b]
Sex			0.5[c]
Female	1 (2.7%)	1 (7.1%)	
Male	36 (97%)	13 (93%)	
Nationality			0.2[d]
Finland	15 (41%)	4 (29%)	
Other EU/EEA country	19 (51%)	6 (43%)	
Non-EU/EEA country	3 (8.1%)	4 (29%)	
Smoking status			0.3[d]
Current smoker	27 (77%)	6 (55%)	
Former smoker	2 (5.7%)	1 (9.1%)	
Non-smoker	6 (17%)	4 (36%)	
Unknown	2	3	
Serotype			0.004[d]
12F	14 (54%)	0 (0%)	
4	11 (42%)	5 (71%)	
8	1 (3.8%)	0 (0%)	
9V	0 (0%)	2 (29%)	
Unknown	11	7	
Living situation			>0.9[d]
Alone	7 (25%)	3 (27%)	
With family	7 (25%)	2 (18%)	
With roommates	14 (50%)	6 (55%)	
Unknown	9	3	
Number of roommates			0.033[c]
1 or less	7 (25%)	7 (64%)	
2 or more	21 (75%)	4 (36%)	
Unknown	9	3	

Characteristic	2019, N = 37[a]	2023, N = 14[a]	*p*-value
Occupational health check before work	14 (50%)	6 (55%)	>0.9[c]
Unknown	9	3	
Main task			0.2[c]
Welder	4 (14%)	4 (36%)	
Other	24 (86%)	7 (64%)	
Unknown	9	3	
Time spent welding			0.7[d]
1-2 hours/day	3 (11%)	2 (18%)	
3-5 hours/day	3 (11%)	1 (9.1%)	
More than 5 hours/day	2 (7.4%)	2 (18%)	
Not applicable/does not weld	19 (70%)	6 (55%)	
Unknown	10	3	
Work environment			0.2[d]
Indoors or mainly indoors	16 (57%)	9 (82%)	
Outdoors or mainly outdoors	1 (3.6%)	1 (9.1%)	
Both	11 (39%)	1 (9.1%)	
Unknown	9	3	
Work sector			0.008[d]
Only wet dock	25 (93%)	6 (55%)	
Only dry dock	0 (0%)	3 (27%)	
Multiple sectors	2 (7.4%)	2 (18%)	
Unknown	10	3	

EU/EEA: European Union/European Economic Area
[a]Median (IQR); n (%)

[b]Welch Two Sample t-test

[c]Fisher's exact test

[d]Fisher's Exact Test for Count Data with simulated p-value (based on 2000 replicates)

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