Does seafarers' limited access to health care increase risk for community-acquired pneumonia requiring hospital care? A longitudinal register-based analysis

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Does seafarers’ limited access to health care increase risk for community-acquired pneumonia requiring hospital care? A longitudinal register-based analysis

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Institution at which the work was performed: Center of Maritime Health and Society, Department of Public Health, University of Southern Denmark

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Authors’ contributions: KH and TP contributed to conception and design of the study. KH analysed the data and drafted the manuscript. KH, TP and JV contributed to the interpretation of the data, critically revised drafts of the work for intellectual content, read and approved the final manuscript to be published and agree to be accountable for all aspects of the work.

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Disclaimer: None

ABSTRACT

Background: Limited access to medical care can be considered as an occupational risk of seafaring and it may predispose to developing community-acquired pneumonia (CAP)

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requiring hospital care. We sought to investigate the risk for CAP and other lower respiratory tract infections (LRTI) requiring hospital care among seafarers. We examined the length of hospital stay (LOS) as a proxy for severity of illness.

**Methods:** The study population in this panel data analysis were all seafarers and a 20% random sample of economically active individuals aged 18-65 years who were residing in Denmark in 1997-2016 constituting more than 11 million person-years of follow-up. Annually registered socio-demographic and work characteristics were linked to data on cause of hospital admissions. We used fixed-effects and zero-truncated Poisson regression to estimate the rate ratios of hospitalization for CAP and other LRTI, and compared LOS across the two populations.

**Results:** The adjusted incident rate ratio (IRR) for CAP in seafarers compared to the economically active population was 1.42 (95% CI: 1.15-1.77), whereas the IRR was 0.73 (95% CI: 0.38-1.42) for other LRTI. For LOS, the IRRs for CAP and other LRTI in seafarers were 1.08 (95% CI: 1.04-1.12) and 0.92 (95% CI: 0.83-1.01), respectively.

**Conclusions:** Our findings indicate that seafaring was associated with an increased risk for CAP requiring hospital care. Limited access to health care may be an important contributing factor.

**INTRODUCTION**

Community-acquired pneumonia (CAP) is one of the leading infectious diseases causing hospitalization and death among adults worldwide [1-4]. Most patients diagnosed with CAP are treated as outpatients, but patients with more severe symptoms, including those for whom diagnosis or treatment is delayed, may need hospital care [5]. Late admission to care of patients with CAP is associated with higher risk for mortality [6, 7]. Acute
Bronchitis, the most prevalent other lower respiratory tract infection (LRTI), affects approximately 5% of adults annually, with the highest incidence observed during the autumn and winter and [8, 9]. As opposed to CAP, acute bronchitis is a self-limited infection, which typically does not worsen even when rapid diagnosis and treatment are not available [8].

Limited access to health care contributes to delayed diagnosis and treatment and can thus be considered as a risk factor for CAP requiring hospital care and mortality, but evidence on the risk of CAP in populations with limited access is still scarce. For example, American Indian and Alaskan Native people, compared with Whites, have been reported to have higher rates of pneumonia-associated hospitalization [10] and mortality [11]. This may be explained partially by a higher prevalence of many risk factors for CAP, such as diabetes, cardiovascular disease, obesity, poverty and low economic status [11], but barriers to accessing health care may be an additional contributing risk factor [11].

Seafarers are an unusual group of workers with specific health concerns and medical care needs. On one hand, to be allowed to work on board a ship, they need to pass regular, typically annual or biannual, medical examinations [12-14]. Furthermore, all ships have a standardized set of medical equipment [14]. On the other hand, in case of illness, their access to medical care is very limited [12, 13]. Instead of conventional medical care, illnesses onboard are typically diagnosed and treated with the assistance of the Telemedical Assistance Service (TMAS) staffed by a specialist team of physicians [12]. The advice and treatment instructions are performed in collaboration with the person responsible for treating illness on board (often the captain or the first officer). In the case of a severe attack of an illness, such as CAP, as a hospital or a doctor’s office is usually located far away, an evacuation is typically carried out by helicopter, the only option to
deliver the patient ashore for hospital care. Evacuations at sea are always massive operations and involve a considerable human as well as economic burden. The risk for CAP among seafarers may represent an important lens to investigate the effects of limited access to medical care on illness that may necessitate hospital care. We are not aware of any previous evidence that helps to quantify this risk.

We hypothesized that seafarers’ limited access to health care could be associated with an increased risk for hospitalization for CAP, but not necessarily with increased risk for hospitalization for other LRTIs because of the self-limited nature of LRTIs. Our aim was therefore to investigate the risk for CAP, and other LRTIs for comparison, requiring hospital care among seafarers, compared with the economic active population. Moreover, we also examined the length of hospital stay (LOS) as an additional indicator for severity of illness, with the assumption that seafarers’ limited access to health care could be associated with longer LOS due to CAP but not necessarily due to LRTI.

MATERIAL AND METHODS

Data sources

All data were obtained by the linkage of Danish national registers. The Danish Civil Registration System was established in 1968 and comprises information on all live-born children and new residents in Denmark, who are assigned a Civil Personal Register (CPR) number [15]. The CPR-number is used to register utilization of healthcare services, and it enables Statistics Denmark to carry out linkages between various data sources at individual level. Data on health-related outcomes were obtained from the Danish National Hospital Register and the Cause of Death Register. The Danish National Patient Register contains information on all in- and outpatients for all hospitals in
Denmark. All registers have full national coverage, and information from the registers are anonymized when used for research.

**Study populations**

The seafarer population constitutes all employees of merchant ships and ferries with a permanent address in Denmark aged 18-65 years in the period between 1997 and 2016. The reference population was formed in several steps. In the first step, the economically active total population aged 15-65 years for the period between 1997 and 2016 was derived from the Danish Civil Registration System. This dataset was divided into two datasets, one for men and another for women. A random sample was then derived from these datasets and then combined to a weighted one to correspond the gender and educational structures of the seafarer population. This final dataset covered a full seafarer population and a 20% random sample of the total Danish economically active population. Individuals not belonging to the economically active population (those who were retired, unemployed for a minimum 6 months annually, and those receiving public transfer payments) were excluded from the analyses.

**Health outcomes**

The primary outcome was hospitalization with CAP or other LRTI as the primary diagnosis identified using classification of the International Classification of Diseases, 10th Revision. We defined hospitalizations for LRTI as hospital admissions for a primary diagnosis of LRTI with at least one night’s stay. Patients were excluded if they were recently, within the previous 30 days, hospitalized for any cause [1]. In all, there were 17,592 hospitalizations due to LRTI (352 in seafarers and 17,240 in the economically active population) of which 88% referred to pneumonia (ICD-10 codes J12-J18, A48.1,
A70) and 12% to other LRTIs (ICD-10 codes J20-J22, J85-J86, A37, A42.0). Out of 15,515 pneumonia hospitalizations 73% referred to other pneumonia (ICD-10 codes J16-J18) and 20% to bacterial pneumonia (ICD-10 code J15). Out of 2,077 hospitalizations due to other LRTI, 57% referred to acute bronchitis (ICD-10 codes J20-J22) and 41% to suppurative and necrotic conditions of lower respiratory tract (ICD-10 code J85-J86).

The length of hospital stay (LOS) was defined as the number of hospitalization days as an inpatient with diagnosis of CAP or other LRTI, and was used as an additional proxy for severity of illness. Hospitalizations with a length of hospital stay over 90 days were excluded from analyses.

**Covariates**

Time-variant social characteristics included age, education, and living arrangement, and these were measured annually over the follow-up period. Age was used either as a continuous variable or grouped into four categories: from 18 to 29 years, from 30 to 39 years, from 40 to 49 years, and from 50 to 65 years. Educational level was based on the highest level of education achieved, and was dichotomized as ‘higher education’, equivalent to bachelor level or higher, or ‘lower education’, equivalent to high school level or lower. Living arrangements was dichotomized as ‘living with other individuals’ or ‘living alone’.

Morbidity data for chronic pulmonary diseases was identified from the Register of Selected Chronic Diseases from the Health Data Authority of Denmark. This register uses information on diagnoses with ICD-10 coding from the hospitalization registers and on medication purchases from the Drug Prescription Register to define chronic pulmonary diseases. The chronic pulmonary diseases included in our analysis were
chronic bronchitis (ICD-10 codes J40-J42), emphysema (J43), other chronic obstructive pulmonary disease (J44), asthma (J45), status asthmaticus (J46) and bronchiectasis (J47). The time of onset of chronic pulmonary disease for subjects in this panel was derived from this register.

**Statistical analysis**

Hospitalization data on individuals between 1997-2016 were extracted from the panel dataset created above, which constituted more than 11 million person-years with mean follow up of 13.6 years (SD 6.9). We used fixed-effects Poisson regression to estimate the associations between the two populations for hospitalization due to CAP and other LRTI. The strength of the fixed-effects models is that it controls for all observed and unobserved time-invariant characteristics of individuals, such as gender, genetic disposition and unchanged health behaviors, and also allows control for observed time-varying covariates, such as age and calendar year [16]. Therefore, the estimated coefficients of the fixed-effects models cannot be biased because of omitted time-invariant characteristics. Parameters for time-invariant variables, such as gender and ethnicity, are not estimated, since they do not change over time [17].

As fixed-effects Poisson regression cannot be used in analyses where the dependent variable is a count variable and restricted to non-zero values, we used zero-truncated Poisson models to assess the association across populations and LOS separately for CAP and other LRTI [18]. We also computed the marginal means of the average LOS derived from these models to estimate and interpret adjusted predictions for sub-groups, while controlling for other variables.
A $P$-value less than 0.05 was deemed statistically significant. All analyses were performed with Stata software, version 16.1 (Stata Corp., College Station, TX, USA).

**RESULTS**

Descriptive characteristics with rates of hospitalization due to any community-acquired LRTI are presented in Table 1. The two populations were relatively equal in distribution owing to our data-generating methods. Living alone was more prevalent among seafarers than in the economically active population with proportions of 37% versus 27% (p<0.001), respectively, and seafarers were more highly educated than the economically active population.

**Association between population and risk of hospitalization due to CAP**

Table 2 shows fixed-effects Poisson regression models for hospitalization due to CAP and other LRTI and their associated factors. The incident rate ratios (IRR) for hospitalization due to CAP and other LRTI were stable across the models regardless of covariates included in the models, which is plausible because of the nature of fixed-effects modelling, which controlled for both observable time-varying factors and observable and unobservable time-invariant factors. Based on the full model, the IRR for CAP in seafarers was 1.42 (95% confidence intervals: 1.15, 1.77) compared to the referent economically active population, whereas this risk was marginal for other LRTI excluding CAP. We also assessed the risk for hospitalization due to CAP separately for those without and with chronic pulmonary disease (Figure 1). The fully-adjusted models excluding individuals with chronic pulmonary diseases indicated that seafarers had a higher risk for CAP than the referent population, with an IRR of 1.44 (95% CI 1.13 to 1.83), whereas the risk was approximately of the same magnitude (IRR of 1.38), but with
wider confidence intervals consequent on the smaller sample size of individuals with diagnosed chronic pulmonary disease.

**Association between population and length of hospital stay**

Table 3 demonstrates zero-truncated Poisson models for the length of hospital stay (in days) due to CAP and other LRTI. The fully-adjusted models show that seafarers had longer in-patient stays due to CAP and shorter stays due to other LRTI, with IRRs of 1.08 (i.e. an 8% longer stay; 95% CI 1.04 to 1.12) and 0.92 (95% CI 0.83 to 1.01), respectively, compared with the economically active population. When patients with diagnosed chronic pulmonary disease were excluded, or when only those with this disease were included, the population effects were of the same magnitude for CAP, with IRRs of 1.08 (95% CI 1.04 to 1.12) and 1.08 (95% CI 0.99 to 1.19), respectively (data not shown).

Due to observed effect modification, we analyzed the association between the populations and the length of hospital stay stratified by educational level (data not shown). Seafarers with lower education were hospitalized longer due to CAP, with an IRR of 1.17 (95% CI 1.12 to 1.22), whereas hospital stays in higher-educated seafarers were shorter than in the higher educated in the economically active population (IRR 0.91; 95% CI 0.85 to 0.97).

**Sensitivity analysis**

Since fixed-effects models do not control for unobserved time-varying factors such as changes in health behavior (e.g., cigarette smoking) within an individual, we conducted sensitivity analyses with a shorter, seven-year observation period. Some health behaviors, such as tobacco smoking, may change slowly [19], and during a shorter
observation period changes in health behaviors are less likely. Supplementary Tables 1 and 2 show, despite the reduced statistical power, that the population effect across the seven-year observation period was to a large extent similar compared with the full 20-year period: seafarers had an increased risk for CAP requiring hospital care, but not for other LRTI.

DISCUSSION

In this large-scale register-based panel study we found that seafarers had a 1.4-fold increased risk for CAP requiring hospital care compared to the economically active population in Denmark. In contrast, this risk was reduced for other LRTI, i.e. for diseases that are primarily self-limiting by nature. We also found that the average length of hospital stays due to CAP was 8% longer, while the average length of hospital stay due to other LRTI was 26% shorter for seafarers compared to the referent group in Denmark.

We are unaware of any previous panel studies that have examined seafarers’ risk for CAP or other LRTI requiring hospital care. Earlier studies on seafarers’ hospitalizations have used broad categories of respiratory diseases that encompassed all ICD-10 codes, chronic lung diseases, under the category of respiratory diseases. These results have been somewhat conflicting: seafaring has been associated both with lower [20] and higher [20-22] risk for respiratory diseases, or this association has been marginal [20-22]. Furthermore, a study without formal statistical analysis concluded that infections were more severe in terms of mortality and hospitalizations than non-infectious events among seafarers [14].

Our finding that seafarers had a 42% higher risk for CAP requiring hospital care compared with the economically active population can be contrasted with other
populations with limited access to medical care. This evidence, albeit scarce and not directly addressing CAP, has demonstrated higher rates of pneumonia-associated hospitalizations and higher pneumonia mortality among American Indian and Alaskan Native people living in remote areas compared with Whites [10, 11]. Although these native populations have several risk factors for pneumonia-related hospitalizations and mortality, including obesity and low socioeconomic status, barriers to accessing health care and delays in treatment are likely additional contributing factors [11].

In addition to limited access to medical care, other potential factors explaining higher risk for CAP requiring hospital care and lower risk for other LRTIs need to be taken into consideration. According to a recent systematic review on risk factors for CAP, cigarette smoking and chronic pulmonary disease were important contributory factors for the increased risk of CAP [23]. However, they are also risk factors for other respiratory diseases. Therefore, it could be assumed that the risk would also be higher for other LRTI among seafarers if cigarette smoking or chronic pulmonary diseases were the main explanatory factors for CAP. However, we found quite the opposite. Moreover, in our analyses we directly adjusted for chronic pulmonary diseases, and also for unvarying cigarette smoking. Furthermore, we performed sensitivity analysis with a shorter, seven-year observation period since it can be assumed that changes in cigarette smoking as a habit are less likely in a shorter than a longer period [19], and these estimates did not differ markedly from those with the longer follow-up period.

Valid estimates on prevalence of smoking among seafarers compared with general working populations are scarce or non-existent. A recent survey on seafarers on Italian vessels reported that 29% were smokers [24], while another small-scale survey with only 335 seafarers reported higher prevalence of smoking compared with estimates for the
general population [25]. An important finding regarding the association of smoking and respiratory diseases in seafarers and other occupations was shown by a large population-based UK Biobank cohort study of over 220,000 current workers [26]. It demonstrated that seafarers had 2.6-fold higher risk of COPD, not only after adjusting for tobacco smoking, but also restricting the analyses to never-smokers. These results were thus free from potential residual confounding effect of tobacco smoking [26].

Our study has several strengths, such as a large-scale, high-quality, population-based sample of residents in Denmark with a linkage to hospitalization registers. This allowed us to conduct a 20-year panel analysis of seafaring and the risk of CAP and other LRTI requiring hospital care. The nationwide closed record system for hospitalizations means that there was virtually no dropout or sample attrition during the follow-up. To our knowledge, this is also the first register-based study to examine the risk for CAP requiring hospital care among seafarers. We also performed analyses using fixed-effect modeling, which controls for both observed and unobserved time-invariant factors.

Our study is not without limitations. First, although limited access to health care is an inherent part of seafaring, we did not measure it directly. Second, we did not have information on clinical judgement, scores and biomarkers which are usually used as the indicators of severity of CAP and that determine whether a patient needs to be admitted to the hospital or not [2, 27, 28]. However, all cases in our study are severe, since they had been admitted to hospital. Moreover, LOS was used as an additional indicator for severity. Finally, despite the several strengths of fixed-effects modeling, it is important to note that this modeling does not control for unmeasured time-variant characteristics of the individuals such as changes in health behavior. Unmeasured changes in health behavior such as tobacco smoking could still confound our results. However, results from
our sensitivity analysis with a shorter observation period indicated the robustness of the results.

Regardless of regular and mandatory health examinations, seafarers had a 42% higher risk for CAP requiring hospital care compared with the economically active population, whose access to health care is likely not similarly limited. Denmark is geographically a relatively small welfare state with a health care system of high quality, and with health care services available for every resident free of charge. TMAS, or other telemedical services assisting patients who are not accessible to conventional medical care, in spite of their valuable importance as part of the health care system, are likely insufficient in illnesses like CAP, for which appropriate and prompt diagnosis and treatment are necessary to prevent illness from worsening.

In addition to reducing other risk factors of CAP, certain measures could be implemented to minimize effects of limited access to health care. Progress in diagnostics via telemedicine would improve treatment and decrease need for hospital care and mortality in CAP and other illnesses not self-limiting by nature. This could include improvements in access to high quality TMAS advice, improving possibilities for medical evacuation, better medical training and awareness by the ship officers on board of symptoms of pneumonia, and enhancing the facilities onboard for appropriate and prompt diagnosis, e.g. through easier access to measurements of biomarkers of infection.

In conclusion, this is the first cohort study to examine seafarers’ risk for CAP and other LRTIs requiring hospital care. Our results indicate that work as a seafarer was associated with an increased risk for CAP requiring hospital care, but was not associated with self-limiting LRTI. These findings suggest that limited access to health care may be an
important contributing factor for CAP in seafarers and others working remotely from sites where medical care can be obtained more readily. Future research with other related populations is needed to confirm our observations.

References


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**Figure legends**

**Figure 1.** Incident rate ratios with 95% confidence intervals for the risk of hospitalization due to CAP among seafarers and the non-seafaring economically active population without (square marker with solid confidence spikes) and with (round marker with dashed confidence spikes) chronic pulmonary disease.
Table 1. Distribution of sample population and rates of hospitalization due to community-acquired lower respiratory tract infections per 10,000 person-years according to demographic characteristics for seafarers (n=233,189 person-years) and the non-seafaring economically active population (EAP) (n=10,781,305 person-years) in 1997-2016.

<table>
<thead>
<tr>
<th>Age groups, years</th>
<th>Seafarers</th>
<th>EAP (referent)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>Rate (SE)</td>
</tr>
<tr>
<td>18-29</td>
<td>24 (4.5 (1.2)</td>
<td>22 (7.0 (0.2)</td>
</tr>
<tr>
<td>30-39</td>
<td>26 (11.2 (1.6)</td>
<td>25 (13.2 (0.3)</td>
</tr>
<tr>
<td>40-49</td>
<td>24 (19.2 (2.8)</td>
<td>26 (15.1 (0.3)</td>
</tr>
<tr>
<td>50-65</td>
<td>26 (25.0 (2.6)</td>
<td>27 (26.8 (0.4)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>78 (15.7 (1.2)</td>
<td>76 (16.2 (0.2)</td>
</tr>
<tr>
<td>Women</td>
<td>22 (13.0 (2.1)</td>
<td>24 (15.2 (0.3)</td>
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<tr>
<td>Educational level</td>
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<tr>
<td>Higher</td>
<td>30 (15.6 (1.9)</td>
<td>23 (15.1 (0.3)</td>
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<td>Lower</td>
<td>70 (14.9 (1.1)</td>
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<tr>
<td>Living arrangement</td>
<td></td>
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<tr>
<td>Married or cohabiting</td>
<td>63 (14.6 (1.3)</td>
<td>73 (16.4 (0.2)</td>
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<td>Living alone</td>
<td>37 (15.9 (1.8)</td>
<td>27 (14.8 (0.3)</td>
</tr>
<tr>
<td>Chronic pulmonary disease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>95 (13.3 (1.1)</td>
<td>94 (13.1 (0.1)</td>
</tr>
<tr>
<td>Yes</td>
<td>5 (48.6 (7.5)</td>
<td>6 (58.9 (1.2)</td>
</tr>
<tr>
<td>Total</td>
<td>100 (15.1 (1.1)</td>
<td>100 (16.0 (0.1)</td>
</tr>
</tbody>
</table>
Table 2. Incident rate ratios (IRR) with 95% confidence intervals (95% CI) for risk of hospitalization due to CAP and other lower respiratory tract infection (other LRTI) among seafarers and the non-seafaring economically active population (EAP).

<table>
<thead>
<tr>
<th></th>
<th>CAP Model 1</th>
<th>CAP Model 2</th>
<th>Other LRTI Mod 1</th>
<th>Other LRTI Mod 2</th>
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<tbody>
<tr>
<td></td>
<td>IRR 95% CI</td>
<td>IRR 95% CI</td>
<td>IRR 95% CI</td>
<td>IRR 95% CI</td>
</tr>
<tr>
<td>Population</td>
<td></td>
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<tr>
<td>EAP (referent)</td>
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<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Seafarers</td>
<td><strong>1.39</strong></td>
<td><strong>1.42</strong></td>
<td>0.73, 0.37</td>
<td>0.73, 0.38, 1.42</td>
</tr>
<tr>
<td>Age</td>
<td><strong>1.08</strong></td>
<td><strong>1.06</strong></td>
<td><strong>1.08</strong></td>
<td><strong>1.07</strong></td>
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<td></td>
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<td></td>
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<tr>
<td>Living alone</td>
<td><strong>0.87</strong></td>
<td>0.82, 0.92</td>
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<td>1.07, 0.91, 1.27</td>
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<td>Education</td>
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<td>Higher education (ref)</td>
<td>1.00</td>
<td>1.00</td>
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<tr>
<td>Lower education</td>
<td>0.96</td>
<td>0.81, 1.26</td>
<td>1.02, 0.66, 1.56</td>
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<td>Chronic lung disease</td>
<td><strong>3.35</strong></td>
<td><strong>3.00, 3.76</strong></td>
<td>2.14, 1.55, 2.94</td>
<td></td>
</tr>
</tbody>
</table>

Model 1 adjusted for age; Model 2 adjusted for age, living arrangement, education and diagnosed chronic pulmonary disease. Statistically significant IRRs are highlighted in bold.

Table 3. The average length of hospital stays in days and incident rate ratios (IRR) with 95% confidence intervals (95% CI) for length of hospitalization due to CAP and other lower respiratory tract infections (other LRTI) among seafarers and the non-seafaring economically active population (EAP).

<table>
<thead>
<tr>
<th></th>
<th>CAP</th>
<th>Other LRTI</th>
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<tr>
<td></td>
<td>Mean (SE)</td>
<td>IRR 95% CI</td>
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<tr>
<td>Population</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EAP (referent)</td>
<td>12.3 (0.03)</td>
<td>1.00</td>
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<tr>
<td>Seafarers</td>
<td><strong>13.2 (0.24)</strong></td>
<td><strong>1.08</strong></td>
</tr>
<tr>
<td>Age</td>
<td><strong>1.01</strong></td>
<td>1.01, 1.01</td>
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<tr>
<td>Calendar year</td>
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<td>0.98, 0.98</td>
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<tr>
<td>Living arrangement</td>
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<td></td>
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</tbody>
</table>

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<table>
<thead>
<tr>
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<th>Not living alone</th>
<th>Living alone</th>
<th>Education</th>
<th>Chronic lung disease</th>
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<tbody>
<tr>
<td></td>
<td>(ref)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Living alone</td>
<td>12.2 (0.04)</td>
<td>1.00</td>
<td>12.5 (0.07) 1.02</td>
<td>13.6 (0.08) 1.00</td>
</tr>
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Statistically significant IRRs are highlighted in bold.