

Occupational health risks due to shipboard cockroaches

Marcus Oldenburg · Ute Latza · Xaver Baur

Received: 23 March 2006 / Accepted: 5 September 2007
© Springer-Verlag 2007

Abstract

Objectives In various investigated populations, sensitization to cockroaches was observed in 8% of screened subjects from temperate climatic zones and in 36% of those from tropical zones. Because of the numerous hiding places and food storages aboard a ship the crews can be highly exposed to cockroaches. The aim of this study is to assess the prevalence of sensitization to cockroaches and potentially associated health risks in seafarers.

Methods In July 2005, a total of 145 seamen sailing under the German flag were recruited from a medical surveillance program for a cross-sectional study (response 95.4%). A standardized interview and a skin prick test (SPT) with nine common inhalant allergens and a cockroach extract (*Blattella germanica*) were performed. In cockroach-sensitized seafarers total and cockroach-specific IgE was measured and lung function tests conducted.

Results In total, 39 seamen (26.9%) were cockroach-sensitized according to SPT results. Presence of cockroach sensitization in seamen from the tropical zone (37.3%) was significantly higher than in seamen from the temperate zone (21.3%) (odds ratio 2.20, 95% confidence interval

1.04–4.66). The prevalence of sensitization to any of the other nine common allergen mixtures tested was lower (between 2.1 and 12.4%). Neither current or past cockroach exposure on board nor cumulative cockroach exposure and time since last cockroach exposure were associated with cockroach sensitization. Among cockroach SPT-positive seamen, cockroach-specific IgE was detected in 52.8%. Five out of 37 (13.5%) SPT-positive seamen exhibited an obstructive ventilation pattern. The prevalence of work-related atopic symptoms was 9.0% ($n = 13$). These symptoms were not related to cockroach sensitization.

Conclusion The high prevalence of sensitization to cockroaches among seamen in the presented study emphasizes the strong sensitization potency of these insects. Longitudinal studies and bronchial cockroach challenge tests are necessary to assess the clinical relevance of cockroach sensitization aboard a ship in more detail.

Keywords Cockroaches · Sensitization · Ships

Introduction

Cockroaches can transmit infectious germs. In addition to this health risks, a sensitizing effect of cockroaches is well known. These insects express potent inhalative and/or digestive allergens (Zwick et al. 1991; Kang et al. 1989; Stankus and O'Neil 1988), identified for example in cockroach saliva, faeces, secretions, cast skin, debris and carcasses (Arruda et al. 2001). Cockroach allergens can be detected in food infested by these insects. Even heating the contaminated food up to 100°C does not destroy these allergens.

Due to international freight transports, cockroaches have spread over the whole world. The risk of a passive spread is

M. Oldenburg (✉)
Department of Maritime Medicine,
Institute of Occupational and Maritime Medicine (ZfAM),
University of Hamburg, Hamburg State Department
for Social Affairs, Family, Health and Consumer Protection,
Seewartenstrasse 10, 20459 Hamburg, Germany
e-mail: marcus.oldenburg@bsg.hamburg.de

U. Latza · X. Baur
Institute of Occupational and Maritime Medicine (ZfAM),
University of Hamburg, Hamburg State Department
for Social Affairs, Family, Health and Consumer Protection,
Hamburg, Germany

relatively high since these insects are very speedy, their resistant oothekas can easily be overlooked and they are able to survive without feed for a long time. The photophobic insects are especially found in warm and damp areas aboard with a rich offer of food. Therefore, galleys with their constant damp climate or storerooms with numerous possibilities of nutrition represent ideal living conditions for these small night-active insects. To the best of our knowledge, no data on cockroach infestation on ships under currently optimized hygienic conditions are available.

Nowadays, ship crews consist of seamen from various countries. Those from tropical regions probably had pre-professionally a higher exposure to cockroaches than seamen from temperate climatic zones. Therefore, the assessment of occupational sensitization to cockroaches due to exposure on ships has to take seafarers' origin from different climatic zones into account.

In a pilot study in Hamburg port in August 2005, cockroach infestation was detected in 6 (10.2%) out of 59 ships regularly transporting freight to and from tropical/subtropical regions (M. Oldenburg et al., in preparation).

So far, no studies have been published dealing with occupational cockroach sensitization in seafaring. The aim of this study was to investigate the prevalence of sensitization to cockroaches and potentially associated health risks among seamen.

Materials and methods

Study population

Every 2 years, seamen sailing under the German flag have to undergo a medical surveillance program to test their fitness for nautical service. These examinations are performed at the statutory accident insurance institution for seafaring ("See-BG") in Hamburg, Germany. During a period of three weeks in summer 2005 (July 25–August 12) the seamen subjected to the check-up were asked to take part in the present study. Informed consent was obtained from 145 out of the 152 workers (95.4%) examined during this time period.

The participating seamen from different nations were assigned to two climatic zones (n):

1. *Temperate zone* (n = 94): Germany (n = 53), Poland (n = 13), Russia/Ukraine (n = 10), Sweden (n = 4), Finland (n = 2), Austria (n = 2), Spain (n = 2), Portugal (n = 2), Romania (n = 2), Croatia (n = 2), Iran (n = 1), Turkey (n = 1).
2. *Tropical zone* (n = 51): Philippines (n = 26), Myanmar (n = 14), Kiribati (n = 7), Indonesia (n = 2), Ghana (n = 1), Cap Verde (n = 1).

The seamen were according to their vocational qualification allotted to two groups: *higher professional training* (n = 59), i.e. captains, officers or cadets; *lower professional training* (n = 86), i.e. crew rank seafarers (ordinary or able seamen, machine workers, kitchen and maintenance staff).

On account of logistic and economic considerations, only cockroach-sensitized seamen in SPT underwent lung function testing and blood sampling for the measurement of total IgE and specific IgE.

Questionnaire

In a standardized interview, especially the current and past exposure to cockroaches on ships, demographic data as well as acute and chronic symptoms of the airways and the skin were recorded. The questions on symptoms are in most parts identical to the questions of the German National Health Interview and Examination Survey 1997/98 (BGS 98) (Thefeld et al. 1999). A subject was defined as having atopic symptoms if rhinitis, conjunctivitis, wheezing or eczema during the last 12 months was reported. If the symptoms were more pronounced on the ship than ashore they were classified as work-related. The current or the past exposure to cockroaches on board was asked by following questions:

1. Have you seen cockroaches on board of your current ship?
2. Did you ever work on ships with infestation of cockroaches? If yes, how long ago and how many years in total?

Allergological tests

The skin prick test was performed by trained assistant medical technicians on the volar side of the seafarer's forearm with a standardized 1 mm pricker (ALK, Hørsholm, Denmark). The mean wheal size was recorded after 15 min. The skin prick test was considered valid if there was no wheal reaction to negative control (saline) and positive control (10 mg/ml histamine) produced a wheal of at least 3 mm in diameter. The test for a specific allergen was regarded as positive if the wheal was at least 3 mm and amounted to at least 50% of the histamine wheal. The subjects were tested with a panel of nine common commercially available allergenic extracts (*Dermatophagoides farinae*, *Aspergillus fumigatus*, pollen of early-, middle- and late-blooming trees, summer herbs, grass mixtures, animal dander mixtures and egg/milk mixture) as well as a commercially available whole body extract of *Blattella germanica* (Stallergenes, Antony, France). Based on own experiences this cockroach was assumed to be the most frequently found cockroach species on ships. Due to the known cross reac-

tivity of various cockroach proteins the SPT of *Blatella germanica* was assigned to be representative for that of other cockroach species.

As an internal control group, 34 European outpatients (non-seafarers) with suspected occupational diseases and without cockroach exposure in the past according to the questionnaire underwent also these prick tests.

For the measurement of total IgE and specific IgE to *Blatella germanica* (whole body), blood was drawn, centrifuged and the serum frozen to -20°C . A few days later, the serum was analysed using the UniCAP fluoroenzyme immunoassay (FEIA) according to the manufacturer's instructions (Pharmacia, Freiburg, Germany). Specific IgE levels above the threshold of 0.35 kUA/l (CAP class 1 or greater) were considered positive.

Subjects with at least two positive skin test responses to the used panel of nine common allergens (with the exclusion of cockroach extract) were considered atopic.

Lung function analysis

Lung function tests were only performed with the cockroach-sensitized seamen. The measurements were conducted by physicians or trained technicians using a portable spirometer (FlowScreen, Erich Jaeger, Wuerzburg, Germany) calibrated according to BTPS criteria (body temperature, pressure-saturated) in the morning of each examination day. Subjects were in a sitting position and had to wear a nose clip.

From at least three forced expiratory spirometers, the forced vital capacity (FVC), and the forced expiratory volume in one second (FEV_1) of each subject were obtained according to the recommendations of the American Thoracic Society (ATS 2005). The ratio $\text{FEV}_1/\text{FVC}\%$ was calculated.

Lung function for the seamen was estimated with reference values by Quanjer et al. (1993) based on a European population. The differences in lung function due to different origins of the investigated seamen were taken into account by applying a correction factor to the corresponding reference values for European people according to the recommendations of Quanjer et al. (1993). For example, the approximate conversion factor for adjusting European reference values of FEV_1 for application to men of Polynesians or African descent was 0.9 and 0.87, respectively.

Statistical analysis

Data were analysed using SPSS for Windows (Version 10.0, SPSS GmbH Software, Munich, Germany). Continuous variables were reported as median values and ranges. For non-parametric comparison of continuous variables by

origin of the seamen, the Mann–Whitney test for two independent groups was carried out. For the comparison of categorical patient characteristics by origin, Fisher's exact test was applied. The ratio between cockroach wheal and histamine wheal was calculated to test whether an association between SPT and specific IgE to cockroaches existed. The Spearman correlation coefficient was calculated. All indicated P values were two-sided and an α -value of 0.05 was regarded as statistically significant.

Binary logistic regression analysis was carried out to assess the magnitude of the effect of one variable after allowance for the effects of other variables. Adjusted odds ratio [OR] and 95% confidence intervals [CI] were estimated. Confounding was defined as a change of more than 15% in the adjusted risk estimates occurred after additionally adjusting for the covariates in separate models.

Results

Cockroach infestation on ships

The interview revealed cockroach infestation especially on container and cargo ships as well as on tankers (in 34.3, 43.4, and 9.1%, respectively). In particular, ships with more than 10,000 gross register tons (53.2%) and older than 10 years (72.7%) were affected. 80.6% of the cockroach-infested ships were regularly operating in tropical or sub-tropical regions. Galley, food storage rooms and crew compartments were the most affected areas on board (43.2, 20.3, and 12.7%, respectively).

Demographic and anamnestic data

At the time of the examination, the participants had a median age of 41 years (minimum 20, maximum 65 years). Seamen from the temperate zone differed significantly from those from the tropical zone in demographic characteristics (Table 1). The seamen from the temperate zone were considerably older, had smoked more cigarettes, and had a longer professional experience on ships. Moreover, they had more frequently a higher professional training than the seamen from the tropical zone (56 (59.6%) vs. 3 (5.9%); Fisher's exact test $P \leq 0.001$).

Twelve (8.3%) of the seamen sailing under the German flag reported a current cockroach infestation on their ship (temperate zone 7 (7.4%); tropical zone 5 (9.8%); Fisher's exact test $P = 0.754$). The seamen from the temperate zone reported more and longer past cockroach exposure on board, and had a longer time since last cockroach exposure. Ninety-nine seamen (temperate zone 71 (75.5%); tropical zone 28 (54.9%); Fisher's exact test $P = 0.015$) were exposed to these insects aboard a ship in the past. The

Table 1 Demographic data on seamen from temperate and tropical climatic zones ($n = 145$)

	Seamen of		<i>P</i>
	Temperate zone ($n = 94$)	Tropical zone ($n = 51$)	
Age, years, median (min–max):	44.5 (20–65)	36 (22–62)	0.005 ^a
Gender			
Male, n (% of total)	91 (96.8%)	51 (100.0%)	0.552 ^a
Female, n (% of total)	3 (3.2%)	0 (0.0%)	
Smoking status, n (% of the respective zone)			0.365 ^a
Non smoker	32 (34.0%)	23 (45.1%)	
Former smoker	20 (21.3%)	7 (13.7%)	
Current smoker	42 (44.7%)	21 (41.2%)	
Packyears, median (min–max)	4.5 (0–108)	0.2 (0–25)	0.003 ^a
Professional experience, years, median (min–max)	20.2 (0.8–50.2)	8.2 (1.3–32.2)	<0.001 ^a

^a Mann–Whitney test

median period of cockroach exposure on board was 1 year (temperate zone 1.8 years; tropical zone 0.5 years; Mann–Whitney test $P = 0.001$). The median time since the last occupational contact to cockroaches was 3 years (temperate zone 5 years; tropical zone 0.3 years; Mann–Whitney test $P = 0.001$).

Cockroach sensitization according to SPT results

In our control group, 6 out of 34 European outpatients (17.6%) with suspected occupational diseases and without occupational cockroach exposure in the past were cockroach sensitized.

In seamen, 39 subjects (26.9%) were sensitized to cockroach (temperate zone $n = 20$ (21.3%); tropical zone $n = 19$ (37.3%)) (Table 2). Seamen from the tropical zone were twice as likely to have a positive SPT result than seamen from the temperate zone (OR 2.20, 95% CI 1.04–4.66). Sensitization to cockroaches was found in 30.2% of seaman with a lower and in 22.0% of those with a higher professional training. Potential confounders were not associated with cockroach sensitization. The association between origin and positive SPT was not confounded by age, gender, packyears, atopy, and cockroach exposure aboard. The weak association between cockroach SPT results and atopy was not significant (Table 2).

Only three women participated in the study. They were all non-smokers from the temperate zone. Similar results regarding the associations investigated were observed when the analyses were restricted to males.

Cockroach sensitization according to specific IgE

Specific cockroach IgE was detectable in 19 out of 36 seamen (52.8%) with positive SPT results to cockroach (temperate zone 35.3%; tropical zone 68.4%; Fisher's exact test

$P = 0.093$). The weal size of the SPT response to cockroach in relation to SPT to histamine correlated with the level of specific IgE to cockroaches (Spearman correlation coefficient; $r = 0.59$, $P < 0.001$).

SPT revealed in 46 (31.7%) of the examined subjects a sensitization to at least one of the tested common allergens, in particular to pollen of summer herbs, *Dermatophagoides farinae*, grass pollen mixtures and/or pollen of early- and late-blooming trees. In total, 23 atopics (15.9%) were found.

A positive SPT result to cockroach was only associated with a SPT response to *Dermatophagoides farinae* (Fisher's exact test $P = 0.001$) (Table 3).

Total IgE was increased in 25 of the cockroach-sensitized subjects (69.4% of this group); especially seamen from tropical zones were affected (89.5 vs. 10.5%; Fisher's exact test $P = 0.010$).

Symptoms

Atopic and work-related atopic symptoms were reported by 43 (29.7%) and 13 (9.0%) subjects. Work-related respiratory symptoms of sneezing, cough, chest-tightness, or dyspnoea were reported by seven seamen (4.8%). Four subjects (2.8%) complained of conjunctivitis in the workplace. Eight seamen (5.5%) noticed eczema related to their work. None of the seamen had an asthma attack during the last 12 months.

Atopic symptoms were associated with atopy (OR adjusted for cockroach sensitization based on SPT 2.57, 95% CI 1.03–6.41) but not with cockroach sensitization based on SPT responses (OR adjusted for atopy 1.05, 95% CI 0.46–2.36). Work-related atopic symptoms were neither associated with atopy (adjusted OR 0.41, 95% CI 0.05–3.34) nor with cockroach sensitization (adjusted OR 1.26, 95% CI 0.36–4.36).

Table 2 Association between origin of seamen and cockroach sensitization: influence of potential confounders including cockroach exposure on board ($n = 145$)

	SPT to cockroach		OR (95% CI) ^a for potential confounders	OR (95% CI) ^a for origin adjusted for potential confounders
	Negative ($n = 106$)	Positive ($n = 39$)		
Origin, n (% of SPT group)				
Temperate zone	74 (69.8%)	20 (51.3%)	Not applicable	1
Tropical zone	32 (30.2%)	19 (48.7%)	Not applicable	2.20 (1.04–4.66)
Potential confounders				
Age, years, median (min–max)	42 (20–65)	40 (21–63)	0.99 (0.96–1.02)	2.19 (1.00–4.76)
Gender, n (% of SPT group)				
Male (vs. female) gender	103 (97.2%)	39 (100.0%)	0.00 (0.00–NE)	2.11 (0.99–4.48)
Packyears, median (min–max)	3 (0–108)	0.6 (0–43)	0.98 (0.96–1.01)	1.95 (0.89–4.27)
Atopy, n (% of SPT group)	16 (15.1%)	7 (17.9%)	1.23 (0.46–3.26)	2.25 (1.05–4.79)
Cockroach exposure on board				
Current, n (% of SPT group)	9 (8.5%)	3 (7.7%)	0.90 (0.23–3.51)	2.21 (1.04–4.69)
Ever, n (% of SPT group)	73 (68.9%)	26 (66.7%)	0.90 (0.41–1.98)	2.23 (1.03–4.83)
Cumulative exposure, years, median (min–max)	1 (0–35)	0.5 (0–30)	0.97 (0.91–1.03)	2.09 (0.95–4.59)
Time since last exposure, years, median (min–max)	2 (0–44)	3 (0–20)	0.97 (0.92–1.01)	1.93 (0.88–4.20)

NE not estimated

^a Odds ratio (OR) and 95% confidence interval (CI)**Table 3** Number of seamen (% of each group) with positive skin prick test (SPT) results for tested common allergens by SPT results for cockroaches

	SPT to cockroach				<i>P</i> *	Percentage of all
	Positive (<i>n</i> = 39)		Negative (<i>n</i> = 106)			
	<i>n</i>	%	<i>n</i>	%		
<i>Dermatophagoides farinae</i>	11	28.2	6	5.7	0.001	11.7
Grass mix	6	15.4	10	9.4	0.371	11.0
Summer herbs	5	12.8	13	12.3	1.0	12.4
Early blooming trees	5	12.8	10	9.4	0.548	10.3
Middle blooming trees	1	2.6	6	5.7	0.675	4.8
Late blooming trees	3	7.7	10	9.4	1.0	9.0
Animal hair mix	3	7.7	4	3.8	0.386	4.8
<i>Aspergillus fumigatus</i>	1	2.6	3	2.8	1.0	2.8
Egg/milk mix	1	2.6	2	1.9	1.0	2.1

* Fisher's exact test

Based on anamnestic data, there was no evidence for an increased frequency of shipboard infectious diseases or endemics in the past.

Lung function tests

Lung function testing according to the recommendations of the American Thoracic Society was performed in 37 out of the 39 cockroach-sensitized seamen. The mean FVC, FEV₁ and FEV₁/FVC% (% predicted) of all seamen were 101.5 (SD 16.7%), 100.5% (SD 19.0%) and 97.3% (SD 13.8%). The seamen from the Tropics showed significantly lower predicted mean FVC values than those from the temperate

zone (Mann–Whitney test; $P = 0.011$). An obstructive ventilation pattern was seen in five subjects (temperate zone $n = 4$; tropical zone $n = 1$; Fisher's exact test $P = 0.340$) (Table 4).

Discussion

This study demonstrates sensitization to cockroaches in 21.3% of the seamen from temperate zones and in 37.3% of those from the Tropics. The higher prevalence in the latter group can be explained by the pre-professional contact due to the more frequent appearance of these thermophile

Table 4 Lung function of seamen with positive skin prick test results for cockroach ($n = 37$) by origin of seamen

	Origin of seamen from		<i>P</i>
	Temperate zone ($n = 19$)	Tropical zone ($n = 18$)	
FVC% ^a (mean (SD))	108.0 (17.0)	94.7 (13.9)	0.011 ^c
FEV ₁ % ^a (mean (SD))	105.1 (18.4)	95.6 (19.0)	0.213 ^c
FEV ₁ /FVC% ^a (mean (SD))	95.1 (13.5)	99.6 (14.1)	0.213 ^c
Obstructive ventilation pattern ^b , n (% of the group)	4 (21.1%)	1 (5.6%)	0.340 ^d

^a Data are expressed as predicted values $\pm$ standard deviation (SD) [reference values by Quanjer et al. (1993)]

^b FEV₁/FVC% < predicted FEV₁/FVC% [lower limit of reference value by Quanjer et al. (1993)]

^c Mann–Whitney test

^d Fisher's exact test

insects in the Tropics and respective frequencies of sensitization in the general population. According to the few available studies on general populations (Carlsen et al. 2002; Hirsch et al. 2000; Kim et al. 1997; Squillace et al. 1997; Leung and Jenkins 1994; Birnbaum et al. 1991), sensitization to cockroaches occurred in 5.5% (from 3.9 to 7.7%) of the subjects from temperate zones and in 21% (from 11.8 to 35.9%) of those from the Tropics. The USA show extraordinary high rates of infestation to cockroaches in households (Huss et al. 2001). Consequently, in the USA high prevalence of cockroach sensitization was described in the general population (26.1%) (Arbes et al. 2005). However, the comparability of sensitization in the available studies is limited due to the heterogeneity in study populations and the different definitions of positive criteria for cockroach-sensitization.

According to the findings of above cited studies, cockroach-sensitization in this study among seamen from the Tropics corresponded to the expected frequency. In comparison with studies on subjects working ashore, the seamen from temperate zones exhibited a higher sensitization to cockroaches. Considering the better vocational qualification of seamen from the temperate zone in this study and thus a better socioeconomic status, a lower sensitization had been expected. However, adjusting the statistical models for indicators of socioeconomic status increased the variance but did not account for the differences between seamen from the temperate and the tropical zone.

Numerous studies on the prevalence of sensitization to cockroaches in risk groups, i.e. atopics, asthmatics, sensitized children, exist (Birkhof 2002; Huss et al. 2001; Mungan et al. 1998; Rosenstreich et al. 1997; Liccardi et al. 1997; Pumhirun et al. 1997; Christiansen et al. 1996; Sarpong et al. 1996; Sastre et al. 1996; Cuesta et al. 1995; Tandon et al. 1990). These studies also describe higher rates of sensitization in risk groups of the Tropics (35%, from 16 to 73%) than in those of temperate zones (16%, from 4.5 to 26%). The authors observed a frequency of

cockroach sensitization of 17.6% in a risk group of German non-seafarers with suspected occupational diseases.

36.8% of 476 investigated children from innercity areas of the United States are sensitized to cockroaches, 34.9% to mites and 22.7% to cats (Rosenstreich et al. 1997). These findings demonstrate the extraordinarily high sensitization potency of these insects being at least equivalent to that of common allergens such as pollen. This assumption is confirmed by other investigations in the USA (Gold et al. 1999).

The prevalence of sensitization to cockroaches on the basis of SPT findings in the present study was much higher than to any common allergen (26.9% of examined subjects). The secondary most frequent sensitization occurred to summer herbs (12.4%) and was thus considerably lower. This underlines the great importance of cockroaches as allergen source on ships. According to the presented results, 68.3% of all seamen reported a shipboard exposure to cockroaches in the past.

Eggleston et al. (1998) regarded levels of the well-characterized cockroach allergen Bla g 1 of ≥ 2 U/g of dust as sensitization-inducing threshold. It can be assumed that seamen have been exposed to cockroaches on ships above this threshold limit. Seamen from the Tropics had probably pre-professionally intensive contact with cockroaches. In contrast, such an exposure is new to the immune system of most seamen from temperate zones. Thus, an occupationally induced sensitization can be assumed for most of the latter seafarers due to their shipboard contact to cockroaches.

The allergenic structures of the different cockroach species are well known (Arruda et al. 2001). Some cockroach allergens show a high homology to allergens of other species (e.g. Bla g 1 with mosquito protein precursor Ang 12). Recently, Tropomyosin (Per a 7) was identified as a major allergen in American cockroaches. Reese et al. (1999) described cross-reactivity between Per a 7 and the respective muscle protein of mites, crabs, lobsters, snails and

shrimps. Witteman et al. (1995) speculated that sensitization to cockroaches often reflects only an immunological reaction to mites' Tropomyosin.

In the present study, a concurrent sensitization to *Dermatophagoides farinae* and cockroaches was detected in eleven seamen (Fisher's exact test; $P = 0.001$). However, 18 seamen were exclusively sensitized to cockroaches and not to mites. This finding is not in favour of a pronounced cross-reactivity.

Approximately only half of the cockroach-sensitized subjects showed IgE antibodies. This corresponds to the observations made in other studies (Carlsen et al. 2002; Sastre et al. 1996). Carlsen et al. (2002) examined 426 Norwegians and found sensitization to cockroaches in 27 persons by SPT, but only in seven by specific IgE measurements. The reason of the small number of positive IgE results remains unclear. Similar phenomena were observed in other sources of allergens, e.g. latex (Dudek et al. 2005). It is possible that some allergens are not appropriately present in the whole body extract or do not bind to solid phases such as CAP sponges, used for IgE assays.

The presented study showed a weak positive correlation between SPT responses and IgE antibody levels to cockroaches. This correlation and the increased total IgE in nearly 70% of cockroach-sensitized seamen refer to an allergic and not to an irritative pathomechanism of SPT responses. The authors assume that positive SPT results reflect cockroach sensitization better than the serological diagnostic testing.

A dose-response relationship was supposed between cockroach exposure and (subclinical) sensitization in exposed subjects (Eggleston et al. 1998). Rosenstreich et al. (1997) demonstrated that an increased frequency of asthmatic symptoms was present only in case of a concurrent high domestic exposure to cockroaches. Gelber et al. (1993) observed an increased asthma frequency among cockroach-sensitized people exposed to levels of Bla g 1 of ≥ 8 U/g dust and defined this level as a disease-inducing threshold. These studies are evidence for a positive association between the level of cockroach allergen and the risk of developing an allergy.

In this cross-sectional study of 145 seamen the prevalence of cockroach exposure on board was not associated with an increased frequency of work-related respiratory symptoms. According to reports of the study participants, they were currently not or only rarely exposed to cockroaches on board. This may explain the absence of symptoms and lung function impairment among seamen in this group who were in the past surely on the average strongly exposed to cockroaches.

Misclassification of the subjective information on cockroach exposure in this study could explain the absence of an exposure-related cockroach sensitization on the basis of the

anamnestic data. It is well known that apparent cockroaches refer to an extensive infestation of these photophobic insects. Thus many seamen might have been less intensively exposed without their knowledge. Moreover, frequent cockroach exposure in the Tropics since childhood may render contact to these insects in seamen from the Tropics less impressive than in seamen from the temperate zone.

Because of logistic reasons, lung function testing could not be performed with seamen non-sensitized to cockroaches. Thus, statements about the level of specific cockroach IgE and lung function of non-cockroach sensitized seamen are not possible.

The high prevalence of sensitization to cockroaches among seamen in the presented study emphasizes the strong sensitization potency of these insects. As a consequence, further studies and bronchial challenge tests with cockroach are needed to assess the health risks due to occupational exposure to cockroaches aboard a ship in more detail.

Acknowledgments The authors thank all seamen who participated in our study. Furthermore, we would like to thank Dr. B. Schepers, M. Böckmann-Friedrich and U. Brettmann of the statutory seafaring accident insurance institution ("See-BG") for their great on-the-spot support. In addition, the authors express their gratitude to the following co-workers from different departments of the Institute of Occupational and Maritime Medicine (ZfAM), in particular to D. Johannsen and E. Nern of the Clinical Department, to Dr. C. Bittner and S. Finger of the Allergy Department as well as to U. P. Huesing, W. Mueller, M. Kalkowski, M. Boeger and Dr. M. Puskeppel of the Hamburg Port Health Authority for their active support during this study.

References

- American Thoracic Society (2005) Standardization of spirometry: 2005 update. *Eur Respir J* 26:319–338
- Arbes SJ, Gergen PJ, Elliott L, Zeldin DC (2005) Prevalences of positive skin test responses to 10 common allergens in the US population: results from the third National Health and Nutrition Examination Survey. *J Allergy Clin Immunol* 116:377–383
- Arruda LK, Ferriani VP, Vailes LD, Pomes A, Chapman MD (2001) Cockroach allergens: environmental distribution and relationship to disease. *Curr Allergy Asthma Rep* 1:466–473
- Birkhof R (2002) Hausstaubmilben und Schaben als Auslöser allergischer Erkrankungen. [Mites and cockroaches as risk factors of allergic diseases] Dissertation, Ludwig-Maximilian-University of Munich, Germany (submitted)
- Birnbaum J, Guilloux L, Charpin D, Vervloet D (1991) Cockroach allergens. *Lancet* 337:249
- Carlsen KC, Carlsen KH, Buchmann MS, Wikstrom J, Mehl R (2002) Cockroach sensitivity in Norway: a previously unidentified problem? *Allergy* 57:529–533
- Christiansen SC, Martin SB, Schleicher NC, Koziol JA, Hamilton RG, Zuraw BL (1996) Exposure and sensitization to environmental allergen of predominantly Hispanic children with asthma in San Diego's inner city. *J Allergy Clin Immunol* 98:288–329
- Cuesta C, Placido JL, Delgado L, Miranda M, Moreira Silva JP, Castel-Branco MG Vaz M (1995) Alergia a la cucaracha: estudio

- de su prevalencia mediante pruebas cutáneas con extractos comerciales. [Cockroach allergy: a study of its prevalence using skin tests with commercial extracts]. *Allergol Immunopathol (Madr)* 23:295–300
- Dudek W, Walusiak J, Wittczak T, Krakowiak A, Marciniak-Bielak D, Raulf-Heimsoth M, Palczynski C (2005) Natural rubber latex allergy: antigen-specific IgE in Polish blood donors, prevalence and risk factors—preliminary data. *Int J Occup Med Environ Health* 18:35–42
- Eggleston PA, Rosenstreich D, Lynn H, Gergen P, Baker D, Kattan M, Mortimer KM, Mitchell H, Ownby D, Slavin R, Malveaux F (1998) Relationship of indoor allergen exposure to skin test sensitivity in inner-city children with asthma. *J Allergy Clin Immunol* 102:563–570
- Gelber LE, Seltzer LH, Bouzoukis JK, Pollart SM, Chapman MD, Platts-Mills TA (1993) Sensitization and exposure to indoor allergens as risk factors for asthma among patients presenting to hospital. *Am Rev Respir Dis* 147:573–578
- Gold DR, Burge HA, Carey V, Milton DK, Platts-Mills T, Weiss ST (1999) Predictors of repeated wheeze in the first year of life: the relative roles of cockroach, birth weight, acute lower respiratory illness, and maternal smoking. *Am J Respir Crit Care Med* 160:227–236
- Hirsch T, Stappenbeck C, Neumeister V, Weiland SK, von Mutius E, Keil U, Leupold W (2000) Exposure and allergic sensitization to cockroach allergen in East Germany. *Clin Exp Allergy* 30:529–537
- Huss K, Adkinson NF Jr, Eggleston PA, Dawson C, van Natta ML, Hamilton RG (2001) House dust mite and cockroach exposure are strong risk factors for positive allergy skin test responses in the Childhood Asthma Management Program. *J Allergy Clin Immunol* 107:48–54
- Kang BC, Chang JL, Johnson J (1989) Characterization and partial purification of the cockroach antigen in relation to housedust and housedust mite (D.f.) antigens. *Ann Allergy* 63:207–212
- Kim YY, Cho SH, Kim WK, Park JK, Song SH, Kim YK, Jee YK, Ha MN, Ahn YO, Lee SI, Min KU (1997) Prevalence of childhood asthma based on questionnaires and methacholine bronchial provocation test in Korea. *Clin Exp Allergy* 27:761–768
- Leung R, Jenkins M (1994) Asthma, allergy and atopy in southern Chinese school students. *Clin Exp Allergy* 24:353–358
- Liccardi G, Russo M, D'amato M, Granata FP, De Napoli A, D'amato G (1997) Sensitization to cockroach allergens in a sample from the urban population living in Naples (southern Italy). *J Investig Allergol Clin Immunol* 8:245–248
- Mungan D, Celik G, Sin B, Bavbek S, Demirel Y, Misirliligil Z (1998) Characteristic features of cockroach hypersensitivity in Turkish asthmatic patients. *Allergy* 53:870–873
- Pumhirun P, Towiwat P, Mahakit P (1997) Aeroallergen sensitivity of Thai patients with allergic rhinitis. *Asian Pac J Allergy Immunol* 15:183–185
- Quanjer PH, Tammeling GJ, Cotes JE, Pedersen OF, Peslin R, Yernault JC (1993) Lung volumes and forced ventilatory flows. Report working party standardization of lung function tests, European Community for steel and coal. Official Statement of the European Respiratory Society. *Eur Respir J* 16:5–40
- Reese G, Ayuso R, Lehrer SB (1999) Tropomyosin: an invertebrate pan-allergen. *Int Arch Allergy Immunol* 119:247–258
- Rosenstreich DL, Eggleston P, Kattan M, Baker D, Slavin RG, Gergen P, Mitchell H, Mcniff-Mortimer K, Lynn H, Ownby D, Malveaux F (1997) The role of cockroach allergy and exposure to cockroach allergen in causing morbidity among inner-city children with asthma. Department of Medicine, Albert Einstein College of Medicine, Bronx, NY 10461, USA. *N Engl J Med* 336:1356–1363
- Sarpong SB, Hamilton RG, Eggleston PA, Adkinson NF (1996) Socio-economic status and race as risk factors for cockroach allergen exposure and sensitization in children with asthma. *J Allergy Clin Immunol* 97:1393–1401
- Sastre J, Ibanez MD, Lombardero M, Laso MT, Lehrer S (1996) Allergy to cockroaches in patients with asthma and rhinitis in an urban area (Madrid). *Allergy* 51:582–586
- Stankus RP, O'Neil CE (1988) Antigenetic/allergic characterization of American and German cockroach extracts. *J Allergy Clin Immunol* 81:563–570
- Squillace SP, Sporik RB, Rakes G, Couture N, Lawrence A, Merriam S, Zhang J, Platts-Mills AE (1997) Sensitization to dust mites as a dominant risk factor for asthma among adolescents living in central Virginia. Multiple regression analysis of a population-based study. *Am J Respir Crit Care Med* 156:1760–1764
- Tandon N, Maitra SB, Saha GK, Modak A, Hati AK (1990) Role of cockroaches in allergy to house dust in Calcutta, India. *Ann Allergy* 64:155–157
- Thefeld W, Stolzenberg H, Bellach B-M (1999) Bundes-Gesundheits-survey: response, Zusammensetzung der Teilnehmer und Non-Responder-Analyse. [German National Health Interview and Examination Survey: composition of participants, and analysis of non-respondents]. *Gesundheitswesen* 2:57–61
- Wittman AM, van den Oudenrijn S, van Leeuwen J, Akkerdaas J, van der Zee Js, Aalberse Rc (1995) IgE antibodies reactive with silverfish, cockroach and chironomid are frequently found in mite-positive allergic patients. *Int Arch Allergy Immunol* 108:165–169
- Zwick H, Popp W, Sertl K, Rauscher H, Wanke T (1991) Allergenic structures in cockroach hypersensitivity. *J Allergy Clin Immunol* 87:626–630