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VIA MEDICA

ORIGINAL ARTICLE

Large-scale helicopter rescue of cruise passengers and freighter crew off the coast of Norway in stormy weather

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ABSTRACT

During a storm on the 23rd of March 2019, southbound Viking Sky *was crossing the notorious Hustadvika bay off Norway with 1373 (915 passengers, 458 crew) aboard when power was lost and the ship drifted towards the shore. Mayday was called at 14:15. When the dropped anchors caught and one engine had started, the ship was about 100 m from the rocky coast. Helicopter evacuation was started at 15:30, but was slightly delayed around 19:00 when 9 crewmembers from a nearby powerless freighter,* Hagland Captain*, had to be airlifted to safety. The helicopter rescue from* Viking Sky *was called off at mid-day on the 24th of March. Using its own engines the ship arrived in Molde at 16:20 with 436 passengers and 458 crewmembers. In all, 479 passengers, many of them elderly and three seriously injured, had been airlifted off the ship one-by-one in rough weather by a relay of 6 helicopters, making this one of the most remarkable helicopter rescue operations ever.*

(Int Marit Health 2019; 70, 2: 79–81)

Key words: helicopter rescue, helivac, search and rescue, passenger ship, cargo ship, cruise ship medicine

INTRODUCTION

Helicopter evacuation (helivac) of a single person from a cruise vessel even under ideal circumstances in daylight and calm weather entails hazards for all involved. The decision to helivac is never taken lightly and when it must be, there is always an atmosphere of nervous excitement aboard.

On the 23rd of March 2019 a cruise ship lost power off the Norwegian coast during a fierce storm and started drifting towards shore. This triggered a major helivac operation and images from the rescue spread widely in the media and on social networks. The continuous news coverage was sometimes confusing and conflicting.

This report aims to give a brief overview of the chain of events surrounding the rescue operation by using selected Internet sources.

MATERIALS AND METHODS

The report is based on international news coverage of the rescue during the period 23 March – 07 April 2019. Information from a basic Google search of "Viking Sky Rescue" was supplemented with selected searches in available international and Norwegian sources when clarification was considered necessary (see references [1–16]).

RESULTS

THE INCIDENT

The main attraction of a 12-day cruise along the coast of Norway at this time of year is to see the Northern Lights (*aurora borealis*). The Norwegian-registered *Viking Sky* (gross tonnage of 47,800) had left the northern city of Tromsø, Norway, where she was christened in 2017, and was bound for the southern city of Stavanger. There were 1,373 persons (915 passengers; 458 officers, staff and crew) aboard. The crew was multinational, while the passengers were mostly an English-speaking mix of elderly American, British, Canadian, New Zealand and Australian citizens. When the ship was passing Hustadvika bay, known for shipwrecks due to fierce weather and shallow waters dotted with reefs, the ship

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lost power (see map — Fig. 1). The ship's four engines shut down in the midst of a storm that heaved up waves as high as 50 feet and wind blowing at 24 m/s (86 kph/54 mph).

Plants and furniture slid across the floors with each tilt of the ship. Ceiling panels fell, and seawater crashed through doors and broken windows. Both passengers and crew reported later that they feared for their lives, but the crewmembers remained calm and there were no signs of panic aboard at any time.

On Saturday 23rd of March 2019 at 14:15 *Viking Sky* issued a mayday call. As the bouncing ship drifted, the crew dropped her two anchors to keep her in place. When the anchors finally caught and the crew had been able to restart one engine, the ship was only about 100 m from hitting offshore rocks.

THE PASSENGER RESCUE OPERATION

At 15:00 it was decided that all aboard should be evacuated. The dangerously high swells meant that the ship's lifeboats could not be safely used and also compelled two purpose-built vessels operated by the Norwegian Society for Sea Rescue to turn back. So the Captain and Norwegian authorities decided to airlift individual passengers to a rescue centre ashore, using a total of six helicopters. Helivac started around 15:30. Flying in the dark, each helicopter airlifted 10–15 persons at the time; slowly winching them up one-by-one from the erratically moving ship. Among the first passengers landed were three with serious injuries.

A SECOND MAYDAY CALL

Just before 19:00 a second vessel, the general cargo ship *Hagland Captain* (gross tonnage 2,984) with a crew of nine, suffered engine failure and started drifting towards the coast some five nautical miles away from *Viking Sky*. Evacuation from the cruise ship was then to some extent delayed because two of the rescue helicopters had to be diverted. The crewmembers of the freighter were told to jump into the frigid water one by one to be picked up by rescuers. The ship was at that time anchored; with part of her timber deck cargo lost. The crew evacuation was uneventful.

THE CRUISE SHIP RESCUE

Helivacs from *Viking Sky* went on throughout the night. On Sunday the 24th of March at 05:00 three of the four engines were working and at 08:00 tugboats were ready, but the helivacs continued. The captain stopped the evacuation before noon, after about half of the ship's passengers had been lifted off. The ship was headed for port, using her own engines. She arrived at the port city of Molde at 16:20, 26 hours after the mayday signal was issued, accompanied by two supply ships and one tug assist vessel. On arrival 436 guests and 458 crewmembers were still remaining on the ship while in all 479 passengers had been airlifted to safety.

Figure 1. Map of Norway. Hustadvika bay is located between Kristiansund and Molde (http://toursmaps.com/molde-norway-map.html)

MEDICAL CONCERNS

All of the passengers and crewmembers survived, though some passengers were injured on board. The two local hospitals, in Molde and Kristiansund (see map — Fig. 1), received a total of 26 passengers. Twelve were treated as outpatients, while 15 were admitted. Three persons were considered seriously injured; one of them was transferred to Haukeland University Hospital in Bergen. According to *The Norwegian Red Cross*, even those who weren't physically harmed had been "traumatised by the experience" and required care on shore.

DISCUSSION

Ships losing engine power along the Norwegian coast is not unusual. More than hundred such cases have been reported just since January 2018 but in most cases the problems were fixed quickly by the ship's crew. The Hustadvika bay is considered a particularly challenging area for seafaring in bad weather. As this emergency situation demonstrated, the regional rescue services were prepared and well trained. Still, successfully airlifting almost 500 persons ship-to-shore during a fierce storm in about 18 hours (≈ 1 person rescued every 2 min) will go down in history as one of the most impressive civilian maritime helivacs ever.

The simultaneous blackout of the nearby freighter was an extra challenge, not least because its nine crewmembers had to be airlifted from the water.

Was the decision to evacuate passengers by helicopters a right one? An external expert (Jan Verloop/FleetMon) stated, “Rescuers were in very dire straits indeed and had to make the choice: whether to launch highly dangerous airlift by helicopters, or wait and pray for lucky escape. I strongly believe that the decision to launch evacuation by helicopters was justified, right, and responsible”. He further expressed admiration for “the professional skills and outstanding bravery of the Norwegian Rescue helicopter teams”.

The importance of a competent *ship crew* in emergency situations should not be underestimated: they dropped anchors and thereby managed to stop the ship from hitting the rocks, they restored power first to one and subsequently to all four engines and got the ship moving again, and they calmed down the very scared passengers. Passengers told reporters afterwards of their deadly fear, but uniformly praised the crew and all involved in the rescue operation for being calm, comforting and professional. The mandatory crew training and frequent drills paid off.

Following preliminary investigations, the *Norwegian Maritime Authority* stated shortly after the incident that relatively low oil levels were the “direct cause” of engine failure. They were within set limits, but the heavy seas in Hustadvika bay probably caused movements in the tanks so large that the supply to the lubricating oil pumps stopped. This triggered an alarm, which in turn shortly thereafter caused an automatic shutdown of the engines. Following the incident, Viking Ocean Cruises have inspected the levels on all their sister ships and are revising the procedures to ensure that this issue cannot be repeated.

When questioned during a Parliament session, the prime minister of Norway reported that a similar large-scale rescue operation in the more northern parts of the Norwegian coast and around Svalbard would not have been possible with today´s resources. Solutions must be found quickly since all-year cruising in these areas continues to increase.

The cruise industry try to avoid bad publicity and near-disasters might therefore not always get the attention needed to identify and correct necessary system errors.

CONCLUSIONS

This massive rescue operation was noticed worldwide, and evaluations will follow. However, debriefings should also include the challenges that might have occurred if the ship had hit the rocks, aiming at thoroughly updated contingency plans for cruise ships and for coastal rescue services.

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ORIGINAL ARTICLE

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Don't forget about seafarer's boredom

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ABSTRACT

Background: *The question we asked was whether it is worthwhile screening for seafarers who are prone to boredom, and whose mental health might deteriorate on board because of the particular character of life at sea.*

Materials and methods: *We used the Farmer and Sundberg Boredom Proneness Scale (BPS), validated in French, as well as the Zigmond and Snaith Hospital Anxiety and Depression Scale (HADS). The survey was voluntary and responses were collected by means of questionnaires which were returned by post.*

Results: *Eighty seafarers (40 officers and 40 crew) as well as 63 office staff from the same shipping company were included in the survey. We found a significant difference between officers and operational personnel: average score of 8.4 ± 5 (median = 7) for officers and 10.2 ± 4.8 (median = 10) for operational personnel. 21% of the officers have scores greater than or equal to 12 compared with 41% of the crew. There is a significant correlation between the BPS and HADS test scores, in terms of depression, for the office staff and the seafarers taken as a whole; this correlation being highly significant among officers (r = +0.85), but only marginally significant among crew members (r = +0.54).*

Conclusions: *The BPS may be useful in screening for seafarers prone to boredom and depression for their fitness for embarkation.*

(Int Marit Health 2019; 70, 2: 82–87)

Key words: boredom, anxiety, hopelessness, seafarers, fitness, stress

INTRODUCTION

Modernisation and automation in shipping impose a monitoring and maintenance culture on seafarers, leading to certain monotony in their work. However, the monotony of the work, increased in the maritime environment by isolation and remoteness, is the breeding ground of boredom at work. This boredom at work is a source of stress and addiction, according to data from the literature (Fisherl [1], Kass et al. [2], Todman [3], Vodanovich et al. [4]). Cummings et al. [5] recently mentioned boredom as a major problem ahead due to the growing industrial automation. Similar studies begin to be undertaken among aircraft pilots and heavy-duty drivers (Bhana [6], Cummings et al. [7]). The question for us is whether it is worthwhile screening for seafarers who are predisposed to boredom, and whose mental health might deteriorate on board because of the particular character of life at sea.

MATERIALS AND METHODS

Boredom at work has been studied, particularly in Anglo-Saxon countries, since the 1980s (Mikulas and Vodanovich [8], Thackray [9], Vodanovich et al. [10], Watt and Hargis [11]). At its most pronounced, it causes a lack of interest and vigilance (Cummings et al. [5], Eastwood et al. [12]) that can lead to mistakes and accidents (Barling et al. [13]). Some jobs with a large number of monotonous, repetitive tasks and no intellectual stimulus can be linked directly to the onset of boredom, especially in road and air transport (Cummings et al. [7], Casner et al. [14]). Finding out whether some people are likely to be bored more easily than others,

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and therefore, when placed in a monotonous environment, could become bored with harmful consequences for the quality of work done, has become a dominant part of studies of boredom at work. Boredom is generally considered an emotion which has a different definition depending on whether we are philosopher, psychologist or psychiatrist. In our work, we adopt the Hill and Perkins (1998) [15] definition which says that boredom occurs when we are faced with a monotonous life combined with frustration. This combination is often found among seafarers, because of the monotony of work on board, routine deck-work or using machinery, being on watch, or doing maintenance tasks, especially at sea. It therefore seemed useful to study this aspect of the psychology of seafarers and draw from it a number of recommendations.

In our study, we used three validated questionnaires: the Boredom Proneness Scale (BPS), the Hospital Anxiety Depression Scale (HADS), and the Job Content Questionnaire (JCQ).

Farmer and Sundberg (1986) [16] have developed a scale known as BPS. This 28-item scale was validated in French by Gana and Akremi [17] in 1998. The internal consistency of the testing is excellent (Cronbach's alpha is calculated at 0.82). One primary component relating to *internal stimulation* (the ability to keep busy, to amuse one's self or be creative) comprises 14 items, a second relating to *external stimulation* (the stimuli of life, the need for diversity and change) has 12 items. We carried out the survey as part of a larger study of stress among seafarers and office staff of a French oceanographic research company. The office staff were at engineer level (a level comparable to that of the officers) or technicians and travelled more or less regularly aboard the same vessels as the seafarers.

The Zigmond and Snaith's [18] HADS, validated in French, studies the anxio-depressive component. Seven questions rating anxiety and depression from 0 to 3 constitute this test. We considered that scores greater than or equal to 11/21 for anxiety and depression were pathological, as recommended by Zigmond and Snaith [18].

The used version of the JCQ is the one validated in French. It is based on the *Job demand-control-support model* of Karasek [19]. It contains 9 questions about *job demand*, 8 questions about *job control*, and 8 questions about *social support*. Responses were rated: –2 for "strongly disagree", –1 for "somewhat disagree", +1 for "somewhat agree" and +2 for "strongly agree". Crossing the data of the *job demand* and *job control* make it possible to classify the subjects in four categories according to whether they are subjected to a strong or weak job demand and according to whether they have a strong or a weak job control in their work. Workers are then categorised as "active" (strong job demand and strong job control), "low strain" (low job demand and strong job control), "passive" (low job demand and low job control) and "high strain" (strong job demand and low job control).

All the seafarers (officers and crew members), as well as the office staff (all male) are French nationals and the vessels operate under the French flag. The oceanographic vessels frequently, but not exclusively, carry out offshore missions (distance greater than 150 nautical miles from a medical facility) lasting from 2 to 5 weeks. Responses were obtained voluntarily by completion of the questionnaire returned by mail to the medical service.

STATISTICAL ANALYSIS

The data collected were processed using the specialised software, SPHINX®. Statistical treatment was conventional: Student t-test for mean comparisons and χ^2 test for population comparisons. Multivariate studies were performed by variances analysis, ANOVA, using the Fischer test. We considered that the threshold for a significant p-value was less than 0.05.

RESULTS

Eighty seafarers (40 officers and 40 crew) and 63 office staff were included in the survey. All are male, the few women seafarers not being included in the survey. The average age is 40.3 ± 7.9 for the officers, 42.3 ± 7.5 for crew members, and 43.6 ± 9.6 for the office staff (no significant difference). Of the crew, 46% are deckhands, 13% are mechanics and 41% are general service staff. At the time of the investigation, all of them were fit for embarkation according to the medical standards in force in France for merchant seamen. There is a significant difference in smoking between officers (40 ± 15.2% are smokers), crewmen (48.7 ± 15.7%) and office staff (17.5 ± 9.3%) (χ^2 = 12.22, dof = 2, p = 0.002). 21.5% of the seafarers take medication, as opposed to 27.4% of the office staff (non-significant difference). But only 12.5% of the officers are on medication while the figure is 30.8% for the crew (χ^2 = 3.9, dof = 1, p = 0.04, significant difference). 2.5% of the officers take anxiolytics and 2.5% take antidepressants, 10.3% of the crew take anxiolytics and 5% take antidepressants, while 6% of the office staff take anxiolytics and 8% take antidepressants.

The results of the Gana and Akremi BPS [17] test are similar for the officers (8.43 ± 5), for the crewmen (10.23 ± 4.77) and for the office staff (9.02 ± 4.92) (F = 1.41, p = 0.24, p = NS). 25% of the officers, 41% of the crewmen and 27% of the office staff have a BPS score greater than or equal to 12/28 (χ^2 = = 2.99, dof = 2, p = 0.22, p = NS). On the other hand, if we compare the officers and crew members, a significant difference is noted: mean scores of 8.4 ± 5 (median = 7) for the officers and 10.2 ± 4.8 (median = 10) for the crewmen (F = 5.02, p = 0.02).

Although the internal stimulation tests yield the same results for officers, crew and office staff, the external stimu-

Table 1. Main results of the Boredom Proneness Scale and the Hospital Anxiety Depression Scale tests (ANOVA)

	Population			Fischer test	P
	Officers	Crew	Office staff		
Average age [years]	40.3 ± 7.9	42.3 ± 7.5	43.6 ± 9.6	1.77	0.17
Boredom disposition score	8.4 ± 5	10.2 ± 4.8	9.02 ± 4.9	1.41	0.75
Internal stimulation score	2.6 ± 2.6	2.9 ± 2.6	2.8 ± 2.7	0.23	0.80
External stimulation score	4.6 ± 2.6	5.8 ± 2.6	4.8 ± 2.4	2.58	0.77
Anxiety score	8 ± 3.7	8.3 ± 3.8	8.4 ± 3.7	0.11	0.88
Depression score	4.3 ± 3.9	5.4 ± 3.1	5.9 ± 3.4	2.35	0.97

Table 2. Results of the Boredom Proneness Scale and Hospital Anxiety Depression Scale tests for seafarers (Officers and crewmen only)

	Seafarers		Fischer test	P	Significance
	Officers	Crew			
Average age [years]	40.3 ± 7.9	42.3 ± 7.5	4.8	**0.02**	**Significant**
Boredom disposition score	8.4 ± 5	10.2 ± 4.8	5.02	**0.02**	**Significant**
Internal stimulation score	2.6 ± 2.6	2.9 ± 2.6	0.84	0.35	Non-significant
External stimulation score	4.6 ± 2.6	5.8 ± 2.6	8.19	**0.05**	**Significant**
Anxiety score	8 ± 3.7	8.3 ± 3.8	0.29	0.59	Non-significant
Depression score	4.3 ± 3.9	5.4 ± 3.1	5.97	**0.01**	**Significant**

lation test results show a significant difference between officers and crew. The results are recorded in Tables 1 and 2.

The HADS test results demonstrate the differences in the non-significant scores between seafarers and office staff. Among seafarers only, the depression average is significantly different between officers and crewmen.

Lastly, if we find a significant correlation between the BPS and HADS test scores for depression among the office staff and the seafarers taken as a whole, this correlation is highly significant for the officers (r = +0.85), but only marginally significant for crew members (r = +0.54) (Fig. 1). Regarding correlation with the HADS test for anxiety, this is also significant between office staff and seafarers taken as a whole, but there is a difference between the officers where the boredom/anxiety correlation is significant (r = +0.69) and crew members where the boredom/anxiety correlation is not significant (r = +0.15).

The results of the JCQ of Karasek [19] are significantly different for the averages of the *job demand* and the *job control* (Table 3) whereas there is no difference for the social support. Compared to the officers and the staff office, the crew is significantly with low *job demand* and *job control* results, which ranks them in the “passive” category (51%). On the other hand, the percentage of “actives” is significantly higher among officers (30% vs. 5.1%), which is logical (Table 4).

DISCUSSION

According to Gana and Akremi [17], boredom proneness is “a tendency to feel a certain lack of interest, enthusiasm and personal commitment, and a tendency to sustain a lack of interest in the surrounding world”. If this proneness to boredom is, in a certain number of individuals, a personality trait that could be regarded as endogenous, a propensity for boredom, as described by Gana and Akremi [17], it is important to ascertain whether for other individuals it is not a reactive state related to the perception of monotony at work linked to frustration, as per the definition of boredom offered by Hill and Perkins [15]. The two commonly accepted factors in boredom proneness (Vodanovich et al. [4, 10, 20], Gana and Akremi [17]), internal stimulation and external stimulation, could represent the two aspects impacted by the two definitions we have just discussed. Internal stimulation gauges general internal support, such as being able to remain interested, and tends more to reflect the endogenous aspect of proneness to boredom. External stimulation gauges the need for excitement, challenge and change with respect to the external environment and would thus be more sensitive to the reactive context.

A “macroscopic” comparison of our seafarer sample (officers and crew combined) yields the same results on the BPS (a mean of 9 ± 4.9 in the two populations and a percentage of subjects with a score ≥ 12 at about 30%).

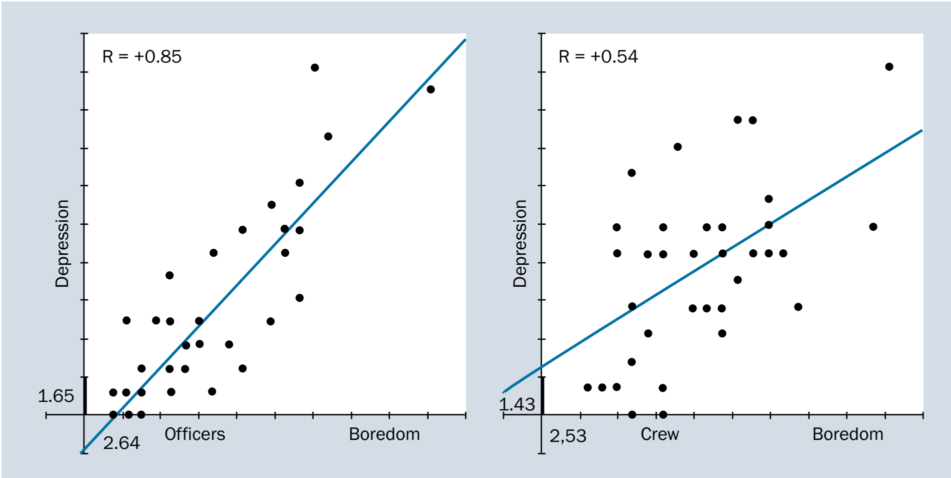

Figure 1. Correlation between depression and Boredom Proneness Scale scores for officers and crew

Table 3. Criteria of Karasek (ANOVA) [19]

		Mean	SD	Fischer	P
Job demand	Officers	0.90	8.29	**5.22**	**0.006***
	Crew	–4.28	6.05		
	Office staff	0.14	8.52		
Job control	Officers	0.31	0.59	**14.91**	**0.001***
	Crew	–0.23	0.56		
	Office staff	0.40	0.59		
Social support	Officers	0.56	0.70	1.77	0.17
	Crew	0.24	0.95		
	Office staff	0.28	0.87		

*Highly significant; SD — standard deviation

Table 4. Ranking in the categories of Karasek [19]

	Active	Passive	High strain	Low strain
Officers	**30%***	**17.5%****	15%	37.5%
Crew	**5.1%***	**51.3%****	17.9%	25.6%
Staff office	34.9%*	12.7%**	11.1%	41.3%

*Significant; **highly significant (χ^2 = 7.79, dof = 2, p = 0.02)

These results are also found in other studies (2006 Culp [21] study: 9.01 ± 4.45).

The exact similarity of the internal and external stimulation scores (Table 1) might suggest individual profiles with the same boredom proneness among the seafarers and office workers. Detailed examination of the results serves to qualify this point of view. Indeed, among seafarers, the results on boredom proneness differ markedly between officers (which are closer to those of the office staff) and crew (deckhands, mechanics and general service staff) (Table 2). Although the internal stimulation scores are the same, there is a clear-cut difference in the total BPS scores, especially in the external stimulation scores where there are many more crew who have a high score. For many of them, this would translate to the existence of a state of boredom due to a lack of external stimulation and, in particular, monotony and the routine nature of the work, a loss of a sense of the meaning of work, or a divergent perception of the passage of time (Table 5).

This difference in perception between officers and crew, aboard the same vessels under similar conditions, allows us to support the hypothesis that relationship with work

Table 5. Comparison between officers and crew (questions of Boredom Proneness Scale)

	Officers	**Crew**
Many things I have to do are repetitive and monotonous	27.5%*	47.4%*
Frequently when I am working I find myself worrying about other things	50%*	76.9%*
Time always seems to be passing slowly	5.6%**	32%**
I often find myself with nothing to do, time on my hands	5.4%*	21%*
I feel that I am working below my abilities most of the time	24.3%**	60.5%**
I am often trapped in situations where I have to do meaningless things	13.5%*	34.2%*
I have projects in mind all the time, things to do	95%**	71.8%**
I would like more challenging things to do in life	50%*	71.8%*

*Significant; **highly significant

has an impact on the external stimulation factor — the external stimulation perhaps being influenced by the living and working conditions experienced by the individual — and the boredom found among the crew being a mixture of "situational" boredom, generated by the monotony of work and "dispositional" boredom directly related to a natural proneness to boredom. The boredom proneness test does not just appear to quantify a personality trait but is also influenced by the level of job satisfaction. Todman [3] has a similar opinion. This is also the opinion of Sawin and Scerbo [22] who consider that the state of boredom and a personality conducive to boredom provoke such an interaction that it is difficult to determine the cause and effect of boredom. It seems clear to us that the level of intellect and training, the interest one finds in the exercise of one's profession, the level of responsibility and involvement in the course of events increase job satisfaction, and it is possible that certain professions generate natural selection leading to the elimination of subjects with a high tendency for boredom (the healthy worker effect). It is interesting to note that this boredom proneness test yielded very poor results for a cohort of 53 male oceanographic researchers and technicians who, for their research at sea, were aboard the same vessels as our seafarers. The test mean was found to be 5.3 ± 2.4 and only 2% had a score greater than or equal to 12.

The criteria of Karasek [19] (Demand-Control-Support model) confirm the results we defend. Indeed, the "passive" category is significantly higher among crewmen (51.3%) than officers (17.5%) and office staff (11.1%) (Tables 3, 4). In fact, the results of JCQ for the officers are quite close to those of the office staff, which is also the case for the boredom proneness.

The "passive" character found in more than half of the crew members confirms the problem with the prime work routine, which is today transformed on modern ships into watch and maintenance work, of no particular interest to these seafarers. In combining the familiar frustrations of separation from family, containment in a confined space, and poor relationships with people on board, we find ourselves absolutely within Hill and Perkins' [15] definition of the conditions for boredom (Table 5).

Many works (Van Hooft and van Hooft [23], Mikulas and Vodanovich [8], Saunders et al. [24]) have demonstrated a strong link between boredom proneness and depression. We find this significant link with depression and, to a lesser extent, with anxiety in our own study among seafarers and office staff. We note, however, that this link correlates strongly with officers (r = +0.85, HS), but does not correlate with crew (r = +0.39, p = NS) (Fig. 1). Among the officers, the two components of internal and external stimulation correlate significantly with the level of depression (respectively 0.85 and 0.65), whereas this is not the case for crew (respectively 0.39 and 0.47). These results confirm that among officers the proneness to boredom is very much related to their psychological state, especially depressive, but this is not the case for crew, whose proneness to boredom is influenced by external factors related to living and working conditions. Van Hooft and van Hooft [25] has recently shown that when task autonomy is low, state of boredom relates to more frustration than when task autonomy is high. When task autonomy is high, state of boredom relates to more depressed affect than when task autonomy is low.

The data in the literature clearly indicate that subjects with a high score for boredom proneness suffer lapses in attention and vigilance (Malkowsky et al. [26]), and stress (Thackray [9], Harju et al. [27]) — hence a possible impact on maritime accidents (collisions, inadvertent course changes) and the increased presence of alcoholism, smoking, drug addiction, gambling addiction and eating disorders (Sommers and Vodanovich [28]), which are also encountered to a significant extent in the maritime environment. Moreover, in our sample of seafarers we find a very high level of smoking, similar to recent data in the literature for French seafarers (Fort et al. [29]). Addiction problems, including alcohol, continue to be a major problem in the maritime environment. The backdrop of boredom that we have described can be considered to be a breeding ground for addictions.

CONCLUSIONS

The Farmer and Sundberg [16] BPS may be useful as part of the fitness for embarkation process, in order to screen for seafarers prone to boredom and depression, especially among crew, who are more susceptible because their living and working conditions on board are more monotonous and less rewarding than those of officers. Although the fitness of seafarers with a score greater than 12 should not apply systematically, other than in cases of obvious depression, we would strongly recommend that there is enhanced monitoring of these personnel.

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Diving, cannabis use, and techniques of neutralisation: exploring how divers rationalise cannabis use

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ABSTRACT

Background: *Diving medicine literature often regards the use of cannabis as a potential contra-indicator for fitness to dive. With that said, there has been no empirical research done with cannabis-using divers to examine how they subjectively understand and construct the risks that their cannabis use may have on their diving. This study explored how cannabis-using divers rationalise the pejorative associations of cannabis use through rhetorical techniques of neutralisation (TON) that function to deny the risks that cannabis use may have on their diving.*

Materials and methods: *Ten medically-fit professional divers from South Africa were individually interviewed. The interviews focussed on each diver's reported recreational use of cannabis. The interviews were transcribed and analysed through a framework for TON originally formulated by Sykes and Matza (1957).*

Results: *Analysis revealed six primary TON employed to refute the pejorative associations of cannabis use on dive work, namely: 1. Denial of responsibility: which denies a diver's direct culpability for their cannabis use; 2. Denial of injury: which asserts that no (serious) harm results from a diver's cannabis use; 3. Denial of victim: which repudiates the potentially deleterious effects that cannabis use may have on a diver; 4. Condemnation of condemners: which minimises cannabis use in relation to other divers' unsafe diving practices; 5. Appeal to loyalties: which situates cannabis use within interpersonal networks to whom a diver has a "higher" allegiance; 6. Denial of penalty: which justifies cannabis use by virtue of a perceived lack of punitive action by a Diving Medical Examiner.*

Conclusions: *The findings of this research highlight the TON which potentially inform a diver's cannabis use, particularly in relation to their diving. Identifying such TON carry important implications for the ways in which fitness to dive is assessed.*

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Key words: cannabis use, diving medicine, diving psychology, techniques of neutralisation, fitness to dive

INTRODUCTION

Cannabis is a psychotropic substance with a history of recreational, commercial, and medicinal use which stretches far back into the annals and practices of ancient civilisations [1–3]. With that said, the politico-legal histories of cannabis, especially in the so-called "West", has been immensely contentious with opinion and science on cannabis use hotly debated and sharply divided [4].

Cannabis, more commonly known as marijuana/marihuana, weed, pot, grass, ganja, and, in South(ern) Africa specifically, dagga, is a combination of plant alkaloids composed by a number of chemical cannabinoids, as part of which the compound delta-9-tetrahydrocannabinol (Δ^9-THC) is typically regarded as the most psychoactive constituent [5]. It is the Δ^9-THC which is largely responsible for the psycho-pharmacological effects which produce the "high" associated with cannabis use [5], and which continue to underpin its status as one of "the most commonly used psychoactive substance" (p. v) [6] around the world. It is also the psychoactive effects of cannabis that have driven

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the long history of legal regulation of cannabis cultivation, selling, and use [4], as well as fuelled more recent moves to have the therapeutic benefits of cannabis legally recognised through campaigns for the decriminalisation and legalisation of cannabis use [7].

In South Africa, the use of cannabis has been prohibited since 1928 [8]. However, in September 2018, a ruling by South Africa's Constitutional Court set in motion the possibility of decriminalising the private use of cannabis [9]. This development has renewed attention to cannabis use and the challenges it poses for South African workplaces [10].

In occupational medicine, cannabis use has long been a concern with regards to occupational health and safety [11]. Given that cannabis has been shown to potentially "impair your concentration, your ability to think and make decisions, and your reaction time and coordination" (Potential impairment from cannabis use is also predicated on a number of other variables, such as, concentration of Δ^9-THC, regularity of use, method of consumption, and other anthropometric factors associated with the user.) (p. 1) [12], its use has typically been a contra-indicator for safety-critical activities, such as driving [13–16], and safety-critical occupations, such as diving [17].

DIVING AND CANNABIS USE

According to St. Leger Dowse et al. [18] the "use of illicit drugs within the diving community is a subject of overdue open debate" (p. 9). The diving medical literature has treated the use of most (if not all) illicit substances by a diver as a potential (if not definitive) contra-indicator for diving [17]. A lack of research on the prevalence/patterns of illicit substance use within the diving community has meant that no conclusive pictures of illicit substance use by divers exist. However, in one of the more sizeable studies focussing on illicit substance use in 479 recreational divers from the United Kingdom, cannabis was found to be the "most frequently used illicit drug" (p. 12) [18] amongst the divers participating in that study.

Professional dive work, be it in the commercial, military, or recreational sectors of diving, is regarded as a "high hazard activity" (p. 4) [19] given the multidimensional risks associated with working in the maritime and (sub)aquatic environments. In this regard, the Diving Medical Assessment (DMA) is a central part of the occupational regulation of safe diving. The primary purpose of the DMA is for a Diving Medical Examiner (DME) to determine a diver's "fitness to dive". The DMA therefore functions as an occupational health and safety tool (for divers) and, at the same time, a medico-legal tool (for state agencies and private organisations who employ divers), which attests to a diver's ability to dive safely and, in turn, minimise the likelihood of diving-related accidents.

The DMA entails a series of objective clinical examinations and tests, conducted by the DME, to determine a diver's physiological and psychological suitability to withstand the personal, occupational, and environmental rigours of diving. The DMA does however also rely on a diver's subjective reports about their own physical and mental health which could impact on their ability to perform dive work safely. This is where it is suspected that divers may under-report illicit substance use, amongst other contra-indicators for diving, to avoid the consequences such reports may have on the DMA outcome [20]. For the full-time professional diver the primary imperative to successfully obtain medical clearance to dive is a matter of financial necessity. Indeed, it is not unusual for research to report on divers not fully disclosing contra-indictors to dive, such as potentially injurious patterns of cigarette and alcohol use [21].

What is of primary interest in this study are the rationalisations which work to both sustain a diver's use of cannabis and, at the same time, function to neutralise the potential risks of cannabis use in relation to their ability to dive safely. Identifying how a diver discursively justifies their use of cannabis through such rationalisations has significant implications for further understanding how they come to perceive, construct, and manage the prospective risks of using cannabis, in relation to their dive work. Understanding how a diver may invest in and employ particular rationalisations within their own talk about cannabis use offers insight into the degree to which possible health care interventions with cannabis-using divers need to be specifically tailored to engage and deconstruct particular rationalisations.

RATIONALISING CANNABIS USE: TECHNIQUES OF NEUTRALISATION

First formulated in Sykes and Matza [22] sociological study of delinquency, techniques of neutralisation (TON) were originally conceptualised as "justifications for deviance that are seen as valid by the delinquent but not by the legal system or society at large" (p. 666). For Sykes and Matza [22], any person who engages in behaviour which could be considered delinquent, deviant, or illegal comes to develop and employ particular TON which specifically function to justify their behaviour by neutralising any pejorative quality or consequence conventionally associated with such behaviour [22].

What is especially interesting in the work of Sykes and Matza [22], as well as those researchers who have adopted and adapted their work [23], is the illustration of how TON are both situationally specific and, at the same time, highly dextrous in their temporal character, that is to say, they can emerge *before* a potentially delinquent act (to help underwrite the underlying motivational complex which makes the act possible), *during* (to rationalise the ongoing pursuit of the act and refute any immediate consequences), or *after* such an act (to protect the actor from any socially pejorative association to the act or from personal feelings of remorse, blame, or guilt). In this regard, there is never a universal character to any TON, but, rather, a set of context dependent socio-cognitive processes which draw from the values, norms, and practices which are contingent to a specific context of potential delinquency [23].

With regard to cannabis use, TON have been studied in non-diving samples [24], in effect helping to reveal the adaptive system of rationalisations which underpin cannabis use and defuse any prospective risk to using cannabis. With little published data on cannabis use by divers, the researchers of this study opted to explore how a sample of cannabis-using divers employ specific TON in an effort to neutralise the pejorative associations that cannabis use may have on their diving.

MATERIALS AND METHODS

STUDY DESIGN, ETHICS, AND PARTICIPANTS

This study draws on narrative extracts of individual interviews conducted with 10 full-time divers from South Africa who reported some measure of recreational cannabis use during the course of a psychological screening interview for their DMA. At the end of this screening, each diver was invited to participate in a research interview focusing on their cannabis use, in relation to their diving. The recruitment of the 10 divers to participate in this study took place over a 3-month period. Ethics approval was obtained from the University of Pretoria's Faculty of Humanities Postgraduate Research Ethics Committee (Ethics Clearance Reference: HUM013/0519), and after each diver supplied informed written consent to participate, their interviews were conducted.

All the divers were medically cleared for diving. The sample consisted of 1 woman and 9 men, with an age range between 21 and 32 years. All had 12 years of formal education in the South African schooling system and had completed the necessary qualifications to be certified in South Africa for professional dive work. All earned their primary income from diving and dived regularly as part of their work.

As a qualitative research interview which aimed at generating in-depth narrative accounts of cannabis use it was determined that the format of each interview would be unstructured. The interview therefore adopted a conversational and non-punitive tone which attempted to disarm potential trepidation about openly discussing cannabis use.

ANALYSIS

Analysis of the transcribed interviews was conducted through a thematic content analysis using the original TON framework formulated by Sykes and Matza [22]. In doing so, the researchers followed a process of (re-)reading the transcribed text with the aim of coding appropriate instances of text within the TON framework. The thematic analysis served an inductive and generative research function which endeavoured to not only constitute the TON framework, but, if need be, to revise the coding framework in the event that data collected did not "fit" the existing analytical frame. To this effect, the researchers were able to derive another TON (*denial of penalty*) that, while not articulated in Sykes and Matza's work [22], was evident in the interview data for this particular sample of divers, and perhaps unique to the South African context.

In what follows, extracts from the transcribed interviews are cited to highlight how this sample of divers applied TON in their talk about their cannabis use in an effort to rationalise and offset any pejorative associations that their cannabis use may have had on their diving.

RESULTS

Analysis revealed that this sample of divers used six primary TON, namely: 1. Denial of responsibility: which denied a diver's direct culpability for their cannabis use; 2. Denial of injury: which asserted that no (serious) harm (had ever) resulted from a diver's cannabis use; 3. Denial of victim: which repudiated the potentially deleterious effects that cannabis use may have on a diver; 4. Condemnation of condemners: which minimised a diver's cannabis use by comparatively evaluating it against other divers' unsafe behaviour; 5. Appeal to loyalties: which situated and legitimised a diver's cannabis use within interpersonal networks to whom a diver had a "higher" allegiance; 6. Denial of penalty: which justified a diver's cannabis use by citing the lack of potential punitive action by a DME. While the first five TON are derived from Sykes and Matza's original framework; the sixth TON was generated through the thematic content analysis of this research data.

DENIAL OF RESPONSIBILITY

For the denial of responsibility TON, the participating divers would deny direct responsibility for their cannabis use by identifying other causative factors as the sources responsible for motivating and sustaining their cannabis use. For most of the participants, the principle causative factor identified was "stress". Interestingly, the kind of "stress" underpinning their cannabis use was typically articulated in two ways: (1) the stress associated with dive work, (2) the stress of working for organisations which employed divers.

In the first account of stress, a participant would describe diving as an inherently dangerous occupation which was accompanied by a significant amount of stress. Here, professional dive work would be contrasted with other more conventional types of work which a diver would not consider as dangerous and, in turn, as far less stressful:

It's stressful this work. You don't just sit at desk. There's lots risks. Lots can go wrong. And you sit with that stress all the time. If you [are] in the water you feel that stress; if you [are] out the water you [are] thinking about the next time you have to go in. It's there all the time. That's why I smoke [cannabis]. It's the only thing that takes that stress out of me (D1 — pseudonym code).

In the second account of stress, participants would invoke their employer or employing organisation as the causal agent of their cannabis use. Participants would discursively position themselves within the common refrain of being "over-worked and under-paid". In this regard, the contractual conditions of a diver's employment would often be identified as a source of stress motivating their cannabis use.

What was often evident in both the above-mentioned accounts of stress is how the denial of direct responsibility would be rhetorically coupled to participants also framing their cannabis use as a technique for helping cope with stress. In this regard, stress was often constructed as both a source for initiating cannabis use and, at the same time, maintaining cannabis use under the guise of being a coping technique for diving-related stress.

DENIAL OF INJURY

The denial of injury TON typically entailed participants refuting any suggestion of the potentially injurious effects of their cannabis use on their ability to dive safely by citing their dive safety record. In other words, a participant would highlight that they have never (subjectively) experienced any deleterious effects from using cannabis on their diving performance. Moreover, participants would report a dive record free of incident/injury to themselves, dive partners, or dive work/tasks. In doing so, the "clean" safety record of a participant would serve as tangible proof that their use of cannabis had no impact on their ability to dive safely:

I've never had anything bad happen. You can speak to any of the guys I've dived with. They know I smoke [cannabis]; but none of them will refuse to dive with me because I've never had anything go wrong. They know I've got a good track record without any fuck-ups (D5).

Interestingly, the denial of injury was also evident in the ways that some participants would unequivocally counteract any alleged negative effects of cannabis use on dive performance by citing "positive" or even performance-enhancing effects of cannabis use. Participants would often point to an array of psychological and physiological capabilities that they believed were enhanced by cannabis use, for example concentration:

Maybe for someone else [smoking cannabis] can slow them down or make them chill out. Not with me. My body responds to it very differently. It's the complete focus. I can actually work a lot better after a spliff (A colloquial term for a cannabis cigarette or "joint"). I'm more focussed... definitely more focussed (D3).

It is worth mentioning that it is not unusual for cannabis users to consider their perceptual and sensory experiences of using cannabis as an objective and often enhanced change in (their sense of) reality [25]. This kind of unconditional positive regard for the reality/performance-enhancing effects of cannabis has also been documented in non-diving samples of cannabis users [26].

DENIAL OF VICTIM

This TON typically involved a participant demonstrating resistance to being discursively positioned as in any way potentially "at risk", "at harm", or "victim to" their cannabis use. This TON would often feature in moments of a research interview where a researcher would suggest potentially deleterious short- or longer-term effects that cannabis use may have on a participant's physical or cognitive competences to dive safely. In response to such suggestions, participants would often rhetorically resist the discursive status of "victimhood" and narratively re-position themselves as "competent" and professional divers, who were fully cognisant of safe diving practice, and, simultaneously, "competent" and well-informed recreational cannabis users, who were fully aware of how to manage their use of cannabis:

I know exactly what I'm doing. I've been smoking [cannabis] for a while so I know how I feel. I'm not a pothead. I don't just light up whenever. I know if I'm diving then I'm not going to smoke [cannabis]. And I will never smoke before a dive. I'm not stupid. But if I've got a few days to myself and I'm not going in the water then I'm gonna smoke [cannabis] (D8).

In these accounts, the denial of victimhood or personal harm was rhetorically underwritten by participants deploying "competency discourses" which functioned to reaffirm their ability to capably and proficiently organise their recreational cannabis use behaviour in such a way that it did not interfere with safe diving practice.

CONDEMNATION OF CONDEMNERS

The fourth TON employed by this sample of divers involved the condemnation of condemners. (The "condemners" here being the DME, other health professionals, and other divers who identified cannabis use as potentially problematic). Put differently, it refuted any suggestion of cannabis use as pejorative, by comparing it with other recreational behaviour or diving practices that would be described by participants as far more harmful. Here, a diver would employ the technique of minimising the risk(s) entailed in cannabis use by comparing it against: (1) other unsafe recreational behaviours allegedly committed by (other) divers, such as excessive alcohol consumption; and/or (2) other unsafe diving practices, such as diving with unsafe equipment.

In the first account, the consumption of alcohol was often identified as a far riskier recreational behaviour. In this regard, participants typically cited instances of (other) divers diving when intoxicated or being partially inebriated:

I know okes (a colloquial term for men) who've gone into the water while their hanging (a colloquial description for a hangover). And that's a hundred time more worse if you think about what alcohol can do if you dive and you've got that in your system (D2).

What is interesting about these accounts, is how they also mirror the ways other non-diving cannabis-users have tended to set-up alcohol consumption as a more pernicious and injurious form of substance use, compared to the use of cannabis [27]. In these accounts, participants often constructed the use of alcohol by divers as a problem far more endemic to the diving community, and a form of recreational behaviour having much more negative implications for a diver's ability to dive safely:

...there's too much focus on this dagga thing. But [the DME] never asks about alcohol. They don't come down on you for drinking too much or if you're hanging and you've had to dive. If you had to ask how many divers are smoking [cannabis] and how many are diving while drunk you would shit. You never let any of us dive again (D7).

In the second account for this TON, participants would cite alleged instances of other unsafe diving practices that required much more attention, as opposed to cannabis use. In one such example, a participant highlighted personal experiences of having to dive (because of occupational/contractual obligations) even when diving equipment was (allegedly) faulty:

...[cannabis use] is not an issue for me. I'm worried about maintenance. The big challenge we have at [Diving Organisation] is maintenance, not weed. Equipment is old, regulators are faulty (D10).

Interestingly, in both accounts of this TON, participants would typically berate their perceived "condemners" by highlighting what were, at least in their eyes, other pejorative behaviours and practices that required urgent attention in the diving community/industry.

APPEAL TO LOYALTIES

This TON could be identified by the way participants appealed to loyalties to whom a participant had a greater allegiance. Here, cannabis use was justified as part of recreational behaviour which was often embedded in (inter-)personal networks for which the use of cannabis was commonplace, normalised, and even expected. A common (inter-)personal network highlighted by participants was their social circle of friends:

I've been smoking with friends forever. If we get together, we smoke. That's not gonna change. That part of my life is very important. I need that chill time from work. If I don't that then you're definitely gonna have book me into [a Psychiatric Hospital] (D4).

Another common (inter-)personal network highlighted were participants' dive buddy/colleague circle. In these accounts, a participant's use of cannabis use was connected to social behaviour which was an expected part of "fitting in" with fellow divers whom they dived and worked with:

About half the guys here smoke [cannabis]. If I didn't join in then I would be sitting on my own (D6).

What is interesting in this particular account, is the way in which D6 positions cannabis use as a pro-social behaviour. This sociability is, at least for D6, vital in affirming inter-personal and occupational allegiances which are themselves an important element of diver safety.

In another account of appealing to loyalties, one participant justified his cannabis use as part of recreational behaviour intimately connected to his ethno-cultural affiliation outside of diving. Here, cannabis use was constructed as a socio-behavioural practice deeply emplaced within an ethno-cultural repertoire of recreational practices. For this particular participant, the cultural valence and personal investment he attaches to what cannabis use means for his own ethno-cultural identity and history ultimately superseded the potential effects that his cannabis use may have on his diving.

DENIAL OF PENALTY

The sixth TON employed by the participating divers is what the researchers of this study have come to call a "denial of penalty" or, more specifically, an assertion of the absence of any significant penalties or punitive action against the participant, even when reporting cannabis use to their DME. An example of this could be seen in the way one participant stated that there no longer existed any punitive action which could be taken against him and his cannabis use, especially in light of the recent court ruling on cannabis use in South Africa:

But it's legal now [to smoke cannabis in South Africa]. So even if I tell [the DME] it's not like she can do anything. And even is she says I can't smoke [cannabis]; I will challenge it because the court said there's nothing wrong with [cannabis use] (D9).

While this particular account demonstrates a rationalisation of cannabis use premised on a belief that the recent court decisions automatically decriminalises and legalises cannabis use in South Africa, this is in fact a misinterpretation of the court ruling. (Readers are referred to the Psychological Society of South Africa's position statement which succinctly clarifies what the ruling actually means for legal cannabis use in South Africa [https://www.psyssa.com/psyssa-position-statement-on-cannabis/]). Moreover, this TON deliberately neglects the existing occupational health standards for divers in South Africa which typically identify any form of illicit substance use as a contra-indicator for diving.

DISCUSSION

THE CONTRADICTING CONSTRUCTION OF RESPONSIBILITY FOR CANNABIS USE: A SHIFTING LOCUS OF CONTROL

One of the more interesting findings from this is that way in which the participants negotiated responsibility for the cannabis use and, with this, demonstrated shifting locus of control. (A person's locus of control generally refers to the degree to which they perceive, experience and attribute their thoughts, feelings, and behaviours to intrinsic [intra-personal] or extrinsic [external] sources [28]). For example, in the denial of responsibility TON, responsibility for a participant's use of cannabis is externalised and attributed to environmental stress, demonstrating an extrinsic locus of control. In the denial of victim TON, divers re-assert their personal agency over behaviour through competency discourse, reiterating a comprehensive knowledge of the risks of diving and the cannabis use, and so demonstrate an intrinsic locus of control. This observation challenges traditional profiling that report a strong intrinsic locus of control among professional divers [29], and suggest that a more nuanced version of divers' sense of agency is required. An understanding of where divers locate control over their behaviour would be an important guide for a DME or allied health professional when engaging divers in health education.

CANNABIS USE AS A CONTRA-INDICATOR TO DIVE? WHAT TON TELL US ABOUT THE COMPLICATED PICTURE OF DETERMINING A DIVER'S PSYCHOLOGICAL COMPETENCE TO DIVE

While the medical literature on cannabis use and diving may be clear that cannabis use typically marks a relative contra-indicator for diving [17, 20], the findings of this study indicate that determining a diver's psychological suitability for dive work is not always as clear cut. In this regard, it is important to note, as we have highlighted in our discussion document "Psychological competency-to-dive: A primer" (available for download from the South African Underwater and Hyperbaric Medical Association [http://www.sauhma.org/psychological-fitness.htm] or on request from the researchers): "psychological performance and mental health [for diving] lies on a continuum... which makes it difficult to determine cut-off points that would guide clinical decision making" (p. 1) [30].

In other words, there are some rationalisations for cannabis use employed by the divers in this study which may be particularly problematic and potentially contra-indicate psychological suitability for diving, such as, the denial of responsibility TON, which may point to compromised judgement. However, other rationalisations may in fact point to the capability of some cannabis-using divers to successfully organise and responsibly manage their recreational cannabis use in a way which does not interfere with their ability to dive safely. For example, in D8's assertion that, as part of the denial of victim TON, he would never use cannabis prior to diving and would confine his cannabis use to periods of non-diving. However, with that said, recognising potentially adaptive and insightful TON on the part of a cannabis-using diver still requires a comprehensive analysis and evaluation of, for example, a diver's judgement, decision-making, and reality-testing, in relation to other rationalisations which may also be employed to justify cannabis use.

THE CONTINUING NEED FOR HEALTH PROMOTION AND HEALTH EDUCATION INTERVENTIONS WITH DIVERS: DEVELOPING MORE SUITABLE TECHNIQUES OF COPING

There is concern about the way many of the participants framed cannabis use as an unproblematic technique for coping with the stress and rigours of diving. This continues to point to the need for the DMA to serve not just as an evaluation of diver's fitness to dive, but, also, as an opportunity for proactive health promotion, especially when it comes to "upskilling" a diver's ability to cope with the physical and emotional demands of dive work. This would reconfigure both the concept and practice of the conventional DMA, bringing it much more in line with developments in preventative occupational medicine and, moreover, how the World Health Organisation (WHO) defines health, namely, as not just the absence of health-compromising factors or disease but as the presence of health-promoting factors and skills [31].

Thus, while the DME has always played an important clinical role in determining a diver's medical fitness to dive, it may also be necessary for the DME to play a more active role as health promoter and educator, especially when it comes to helping the diver develop more adaptive coping skills. Here it may be helpful for the DME who feels under-skilled/ /qualified in the area of psychological skills building to refer a diver to a psychologist suitably experienced in the emerging sub-field of diving psychology [30], and who can help a diver work on a programme of behaviour modification which is practically suitable within the very unique demands of a diver's lifestyle and work environment. Expanding the repertoire of adaptive coping techniques that a diver has available to help them manage stress is incredibly important, especially given the weight of research which already documents problematic patterns of alcohol [32], cigarette [21], and illicit drug [18] use amongst divers.

In the same vein, it may be necessary for those medical practitioners and allied health professionals working with divers to play the role of health educators, particularly when it comes to debunking myths about cannabis use in the wake of moves across the world to, in some instances, decriminalise, and, in other instances, legalise, the use of cannabis. While this kind debunking may seem self-evident, it cannot be taken for granted, especially given that not all legislative changes in regards to cannabis use mirror the medical norms and standards for diving and the determination of a medically fit and psychologically competent diver.

CONCLUSIONS

The findings of this qualitative study highlighted how a sample of cannabis-using professional divers from South Africa rationalise their recreational use of cannabis by neutralising possible pejorative associations with their ability to dive safely. In this regard, the participating divers were shown to employ TON which, albeit in qualitatively different ways, ultimately function to the same end, namely, to defuse the negative connotations associated with cannabis use and its potential effects on safe diving, in order to justify its ongoing use.

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CASE REPORT

Maritime field studies: methods for exploring seafarers' physical activity

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ABSTRACT

In order to determine the health status of seafarers, questionnaires are frequently applied or medical/ /psychological examinations conducted ashore, for example, in the form of medical fitness examinations or simulator training. In such a survey design, the occupational influences and the individual reaction cannot be ascertained. However, these aspects are especially important in the maritime context as employees on board are often exposed to the typical shipping-related stressors in the workplace for many months, both during working hours and during leisure time. In particular, it is assumed that working on board requires a high level of physical effort. Therefore, an exploration of occupational stress and strain, particularly the assessment of the seafarers' physical activity, should preferably be carried out in a comprehensive and realistic way in a maritime field study, i.e. an on-the-job survey directly on board.

(Int Marit Health 2019; 70, 2: 95–99)

Key words: activity on board, daily report, energy expenditure, heart rate, voyage episodes

INTRODUCTION

In order to determine the health status of seafarers, questionnaires are frequently applied or medical/psychological examinations conducted ashore, for example, in the form of medical fitness examinations or simulator training [1, 2]. In such a survey design, the occupational influences and the individual reaction cannot be ascertained. However, these aspects are especially important in the maritime context as employees on board are often exposed to the typical shipping-related stressors in the workplace for many months, both during working hours and during leisure time [3, 4]. In particular, it is assumed that working on board requires a high level of physical effort [5]. Therefore, an exploration of occupational stress and strain, particularly the assessment of the seafarers' physical activity, should preferably be carried out in a comprehensive and realistic way in a maritime field study, i.e. an on-the-job survey directly on board.

MATERIALS AND METHODS

In the following Table 1 [6–9], three complementary instruments for measuring seafarers' activity on board and the resulting strain are presented. These instruments were tested holistically in a (*blinded*) maritime field study and the informative value of these three combined instruments will be demonstrated by means of three case reports.

DAILY REPORT OF PHYSICAL ACTIVITY/VOYAGE EPISODE

All seafarers were requested to keep an accurate daily report for 5 minutes without gaps. On a continuous timeline from 0:00 to 24:00 each day they were to mark which activity level applied to them. The following levels of activity were distinguished: working hours, free time and sleeping time.

In addition, the examiner was able to record, down to the minute, the voyage episode (stay in port, river or sea passage) in which the ship was located at a given time according to a ship's journal.

ACTIVITY PROFILE/ENERGY EXPENDITURE

The SenseWear® armband monitor is designed to quantify physical activity (lying or sleeping time, high physical activity) and to measure seafarers' energy expenditure as metabolic equivalent of task (MET). This monitor is a light-

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Table 1. Selected instruments for measuring seafarers' activity on board

Measuring instruments	Parameters	Previous use in maritime field studies	Remarks
Daily report of physical activity related to voyage episodes	Anamnestic activity level	Harma et al. [6] Ferguson et al. [7] Eriksen et al. [8]	Each seafarer independently noted down their own activity, lying and sleeping times
SenseWear armband monitor; Fa. Bodymedia	Activity monitoring; energy expenditure	Gander et al. [9]	These devices do not restrict the seafarers in their daily work
Polar watch RS 800 Multi (chest strap)	Heart rate/variability		

weight 82-gram device worn on the right upper arm above the triceps muscle. The attachment with an elastic strap provides a high level of comfort; there is no wiring. The monitor measures physiological parameters (2-axis accelerometry, heat flow, skin temperature and galvanic skin reaction (skin impedance) using four different sensors.

In maritime field studies, the physical activity, heart rate and energy expenditure of seafarers should be continuously measured over a minimum of 2 days. The armband monitor has already been tested and successfully used as an activity measuring system in numerous studies [10, 11]. This device has also been repeatedly used in occupational medicine [12, 13].

HEART RATE (VARIABILITY)

Measuring heart rate and heart rate variability as important parameters of the psychophysical strain on board is possible with the Polar watch RS 800 Multi. For this measurement, an elastic chest strap and a special wristwatch (transmitter and receiver) are worn over a period of at least 48 hours. The wearer is hardly hampered in his work routine as no wiring is involved.

It should be noted that artefacts in the derivation (possibly triggered by ship-related sources of interference) but also cardiac arrhythmia can lead to false measurements of the heart rate. Therefore, an artefact correction must be performed; heart rates > 200 bpm and < 35 bpm can be interpreted as artefacts and should not be considered in the evaluation. Non-physiological heart rate sections ("hum frequency") are cut out.

The Polar watch has already been used in various studies [14–16].

HOLISTIC ASSESSMENT OF SEAFARERS' PHYSICAL ACTIVITY

In parallel measurements, 3 seafarers representing different shipboard groups wore the Polar watch simultaneously with the armband monitor for an uninterrupted period of at least 4 days. After merging the data in a spreadsheet programme, the continuously measured heart rate and the energy expenditure were holistically displayed and evaluated for each occupational group, taking into account the various voyage episodes (Port stay, River passage and Sea passage) and the activity level marked in the daily report. The wearing compliance, especially of the armband monitor, was excellent at over 92%.

The holistic activity assessment of a nautical officer (assigned to a 4/8 watch system, i.e., alternating 4-hours watch and 8-hour-free shift), a deck rating and an engine room employee is illustrated in Figures 1–3. In these figures, the voyage episodes in the time stream from the beginning to the end of the parallel survey is shown in the lowest strip and differentiated by colour. The uppermost strip represents the activity phases (working hours, free time and sleeping time) noted in the daily report. The second, third and fourth upper strips correspond to the phases "sleeping time", "lying time" and "high physical activity" recorded by the armband monitor. The upper red curve shows the time-adapted heart rate measured by the Polar watch, and the green curve represents the METs assessed by means of the armband monitor. As expected, a parallel course of the heart rate and the METS is found during all noted activity levels in the following examples.

EXAMPLES FOR THE HOLISTIC ACTIVITY ASSESSMENT ON BOARD

NAUTICAL OFFICER

Figure 1 illustrates that the investigated nautical officer routinely followed a 4-hour watch shift during the sea passage (red bars in the daily report strip during phases of the sea passage marked "green" below in the voyage episodes strip "SP"). This period was followed by an approximately 8-hour-free shift (lime or dark green bars in the daily report strip). During the port stay ("PoS", green bar in the voyage episode strip below), the work assignment switched from a 4/8 to a 6/6 watch system with up to 7 hours of work and short interim breaks.

Overall, this holistic activity assessment reveals how irregular the working hours for the nautical officer were, primarily in the port and adapted to the respective voyage episodes. This illustrates exemplarily that a regular 4/8 watch system for nautical officers is only partially feasible in practice.

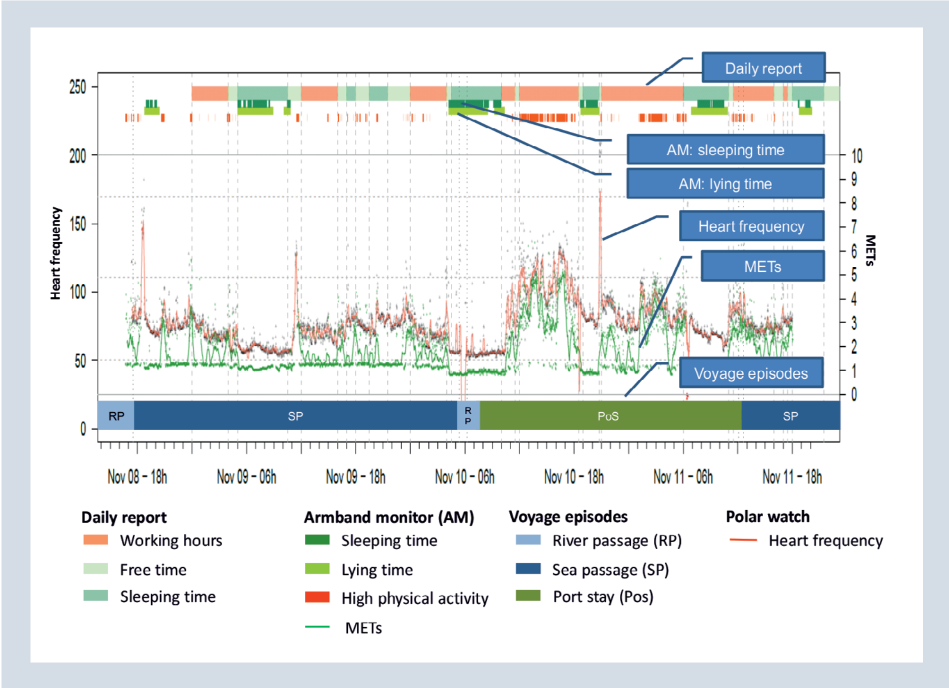

Figure 1. Holistic activity assessment of a nautical officer; MET — metabolic equivalent of task

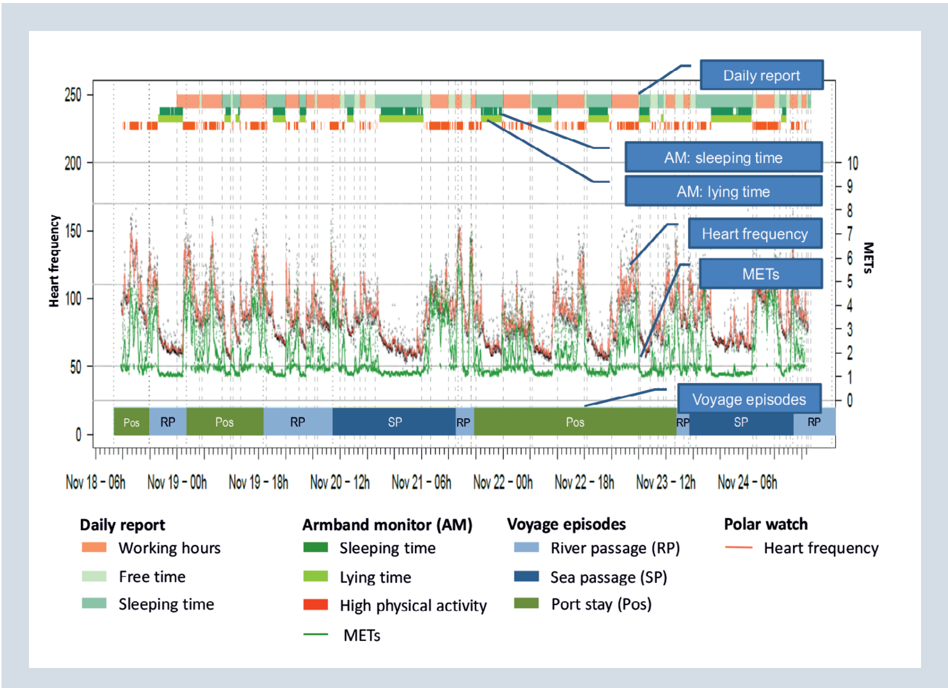

Figure 2. Holistic activity assessment of a deck rating; MET — metabolic equivalent of task

DECK RATING

During the labour-intensive voyage episodes of port stay and river passage, the observed deck rating's work routine was characterised by numerous episodes with several working hours and only short breaks (Fig. 2). During the work phases, repeated heart rate spikes of up to 150 bpm were noted, indicating an increased physical effort. The investigation on board by the examiners revealed

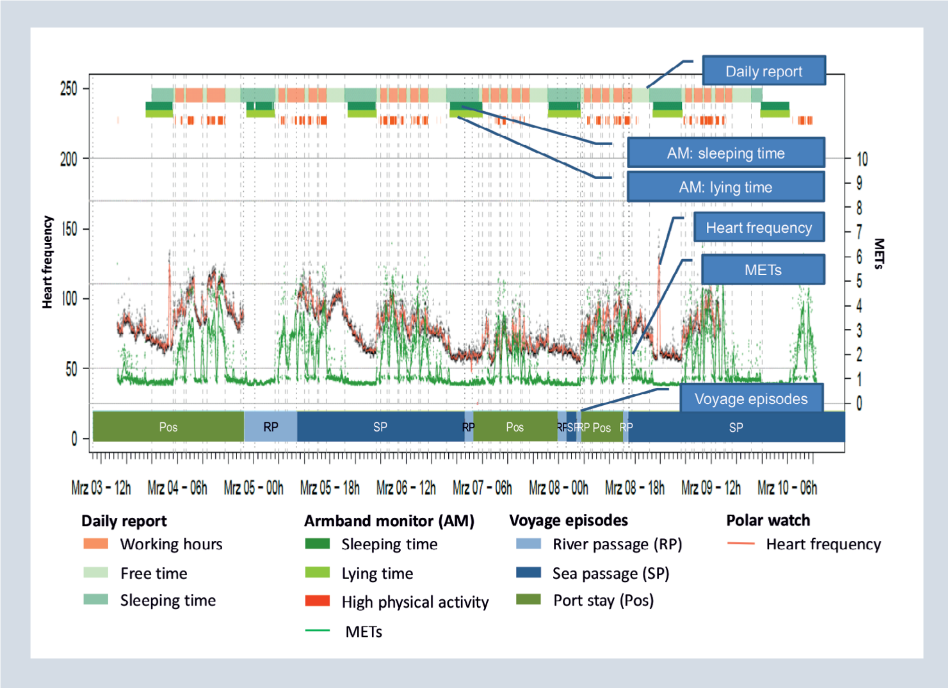

Figure 3. Holistic activity assessment of a crew member from the engine room; MET — metabolic equivalent of task

that the deck ratings had carried out extensive loading and unloading activities during port stay (in particular connecting and stabilising the containers with heavy iron bars; so-called "lashing"). At the same time as lashing was carried out, the heart rate peaked (red curve) and elevated METS (green curve) were observed, which means a high level of physical exertion. Thus, supplementary expert observations made it possible to assign biometric stress reactions to specific work-related situations. Furthermore, Figure 2 shows that the work intensification in the port was compensated during the sea passage by longer free time and sleeping episodes.

ENGINE ROOM EMPLOYEE

In contrast to the watch-keeping crew, the work schedule of the engine room personnel corresponded to a relatively constant day shift system, which was even practiced regardless of the voyage period, as shown in Figure 3.

LIMITATIONS OF A MARITIME FIELD SURVEY

A maritime field study has the following limitations that have to be considered in the evaluation of the results [4].

FIELD SURVEY

A scientific evaluation during the operation of a ship in the sense of a "field study on board" requires a lot of effort due to frequent crew changes, the limited duration of a study and the other uncontrollable variables in the maritime setting. Significant limitations in the evaluation of such a field study are:

- a small study sample (per container ship a maximum of 25 people);
- insufficient detection of long-term effects due to the cross-sectional design of the study on ships with ever-changing personnel on board;
- multinational crews with different socio-cultural backgrounds;
- multiple labour and environmental factors (e.g. shipping area, crew groups, voyage episodes, duty on board, swell); this results in confounding and non-controllability of synchronously influencing factors;
- difficulties of the multinational crew with language understanding.

UNCLEAR REPRESENTATIVENESS OF THE PARTICIPATING SHIPPING COMPANIES

When recruiting the study sample, all shipping companies willing to participate should first be included in a study. However, it should be examined whether the selected shipping companies are representative of the respective survey population with regard to the crew structure and the underlying safety standards. In principle, it cannot be ruled out that shipping companies with worse working conditions on board do not participate in a study, which would result in a selection process. Although this cannot be verified by data, it is more likely to underestimate the workload and stress in the sample being studied.

SMALL SAMPLE SIZE

Due to the elaborate study design of a maritime field study, it is often only possible to compile a relatively small study sample. This leads to the problem that a differentiated stratification of stress and strain is only partially possible, for example, for the various occupational groups on board.

VALIDITY OF THE PHYSIOLOGICAL MEASUREMENT METHODS

In general, the examiner should take into account that the physiological measurement methods in cross-sectional studies only record acute biometric responses. Long-term effects in terms of long-term demands can generally not be determined with these methods, since the measurement results are acutely influenced by occupational (and possibly also non-occupational) effects. The presence of the examiners on board and, in general, the investigation situation (for example, the use of a measuring instrument, regular saliva sampling) could also influence the stress on board. Therefore, care should be taken during the field study to ensure that the examination on board has the least possible effect on the crew's work routine (for example no wiring of subjects with heavy or motion-limiting measuring devices). In addition, many examinations should take place after several days of examiners' presence on board so that contact and a first basis of trust can be established with the crew.

Despite the limitations mentioned above, maritime field studies are indispensable for estimating the need for preventive measures in merchant shipping, since only concrete and up-to-date measurements on board can reveal and objectify burdens in ship operation. The recording of the physiological response to a shipboard stressor, i.e. the strain of the ship's crew, also remains reserved for the methodical approach of an investigation on board. Surveys ashore, for instance, ship simulator trainings, are not suitable for exploring the ship crews' workload, which typically lasts several months on board, and its long-term effects.

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Musculoskeletal symptoms among workers in the commercial fishing fleet of Norway

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ABSTRACT

Background: *Fishers exposed to unfavourable environmental conditions may suffer negative health effects. This study aimed to identify musculoskeletal symptoms in professional fishers in Norway using data from several sources; register data, telephone survey and questionnaire.*

Materials and methods: *Professional fishers (n = 25,971) registered in the period 2008–2013 were selected by Statistics Norway (SSB). An age- and gender-matched control population (n = 77,913) was also selected. Outpatient consultation and hospitalisation data were received from the Norwegian Patient Registry (NPR). To obtain information about self-reported symptoms, 832 registered fishers on board Norwegian fishing vessels were interviewed by telephone, and a questionnaire was distributed to the crews of 5 trawlers (n = 153).*

Results: *Data from NPR showed that fishers, compared to the control population, suffered significantly more acute incidents related to musculoskeletal disorders (5.4% vs. 4.8%, respectively), injuries to arms (11.3% vs. 9.8%), feet (8.4% vs. 8%), and back (0.9% vs. 0.7%). In the telephone survey, 61% and 43% reported that they performed monotonous work operations and heavy lifting often or very often, respectively. Thirty-three per cent had experienced pain in neck/shoulders/arms often or very often during the previous 12 months, and 93% believed this was fully or partly due to their work situation. The questionnaire among trawler crew members showed that 57% and 60% had experienced stiffness and/or pain in neck/ /shoulders and lower back/small of the back respectively during the previous 12 months.*

Conclusions: *Data from the register study, telephone survey and questionnaire all confirmed that musculoskeletal problems are common among fishers and related to their work situation. However, 77% of the fishers in all vessel groups and on board the 5 trawlers reported their own health as being very good or good.*

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Key words: fishing, musculoskeletal disorders, registries, telephone survey, questionnaire, occupational health

INTRODUCTION

The fishing fleet in Norway employs people on board different types of vessel, ranging from owner-operated coastal vessels to large deep-sea factory trawlers with up to 30 crew members, which mostly operate in the Barents and Norwegian Seas [1]. Workers in the fishing fleet may be exposed to a variety of unfavourable conditions such as cold, changing temperatures, repetitive work tasks, heavy workloads, noise, inconvenient working hours, long work days and high level of stress. As a result, they are likely to be negatively affected in terms of health and work performance [2–4]. Several ergonomic stressors at all stages of fishing dictated by some unpredictable factors such as weather conditions, as well as type of vessel, gear in use, crew size and level of experience are identified [5]. A Danish study concluded that despite positive developments in the physical work

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environment, fishers still experience heavy workloads and suboptimal ergonomic conditions [6].

Musculoskeletal disorders (MSD) are reported to be the most common cause of sick leave, directly affecting individuals and indirectly, health care and social security systems [7–10]. A recent study of Norwegian fishers found several health challenges (including MSD) related to exposures in the work environment such as repetitive and monotonous work operations and heavy lifting [4]. The same study also found that about 50% of fishers' doctor-certified sick leave in 2013 was due to MSD [11]. Studies from other countries show that there is a connection between fishers' work and MSD. For instance, vessel movement has been pointed to as a cause of musculoskeletal stress for fishers, which is aggravated by lifting or carrying weight [12]. Similarly, musculoskeletal symptoms were found in a sample population of American fishers, especially in the lower back and hands or wrists, and were a common reason for impaired work performance [5]. Another American study identified several occupational risks that might contribute to cumulative MSD, such as repetitive work, forceful exertions, awkward or static postures, low temperatures, vibration and muscle strain caused by the need to continually maintain balance [13]. Studies from other occupations show that cold, wet and windy conditions also negatively affect work performance, comfort, and that cold-related health problems (such as rhinitis, muscle pain, back pain, white fingers/Raynaud's syndrome, difficulties in breathing), are likely to occur more frequently at low ambient temperatures than in warm environments [14–19]. Low-intensity repetitive work in cold (5°C) environments may negatively affect muscle function and cause fatigue [20], which may lead to overuse injuries and MSD in the long run [21]. Research in onshore seafood production plants found that the low temperatures needed to ensure high-quality fish products can increase the risk of symptoms in muscles, skin and airways [22, 23]. Studies from Iceland made similar findings on the prevalence of musculoskeletal symptoms, particularly among workers performing repetitive and monotonous tasks [24]. These findings are thought also to be relevant to trawlers with on-board processing of fish. Lipscomb et al. (2004) [5] pointed out that reducing ergonomic exposures among commercial fishers is important.

During the past few years analyses show a decline or stagnation in personal accidents in the Nordic fishing fleet [25]. The focus for research and regulation in the Norwegian fishing fleet has been acute injuries and fatalities [26, 27] and most of the literature has also focused on this aspect [28]. However, there is still a lack of research-based knowledge regarding interactions between work, the work environment and occupational health among Norwegian fishers. This gap in our knowledge also includes several musculoskeletal disease subgroups.

Our aim was to study symptoms of musculoskeletal disease among occupational fishers in the Norwegian fishing fleet using three different research methods. We hypothesised that use of official sickness absence register data, a telephone survey and a questionnaire would demonstrate that MSD were the main cause of sickness absence, and that exposure to the work environment on board fishing vessels results in a higher incidence of musculoskeletal symptoms.

MATERIALS AND METHODS

We combined quantitative (registries, questionnaire study) and qualitative (telephone survey) methods (methods triangulation) [29]. The three methods used covered different sample populations of occupational fishers. The register data are based on doctor certified sickness absence due to MSD in more than 25,000 fishers in the period 2008–2013. Respondents in the telephone survey were identified and selected in 2014 through Norway's official register of fishers (n = 832), while the questionnaire (n = 153) included crew members on five trawlers operating in the Barents Sea in 2013–2015.

REGISTRIES

A sample of fishers (n = 25,971) was drawn by Statistics Norway (SSB) based on the Standard Industrial Classification (SIC2002/2007) and the Standard Classification of Occupations (ISCO-88/08) for fishers between 2008 and 2013. An age- and gender-matched control population (n = 77,913) was drawn for comparative analysis. Sick leave and diagnosis data were obtained from the Norwegian Labour and Welfare Administration (NAV), while hospitalisation data (inpatient and outpatient data) were obtained from the Norwegian Patient Registry (NPR). Diagnoses leading to sick-leave were categorised in accordance with the International Classification of Primary Care, second edition (ICPC-2), while the International Classification of Diseases, tenth edition (ICD-10), is the standard classification tool for hospitalisation data. The data from SSB or NAV were coupled to data from the NPR. SSB forwarded the Social Security number of the population directly to the NPR from where the researchers received an anonymised data file.

TELEPHONE SURVEY

A total of 1,000 registered fishers on board Norwegian fishing vessels participated in a telephone survey in 2014. Respondents were identified through the official fisher registry in Norway, and 832 were active fishers at the time of the survey. The mean age of the respondents was 50 years old and 2% were women. The same study population as reported by Sønvisen et al. (2017) [4] was used.

The telephone survey comprised 99 questions, a few of which concerned musculoskeletal symptoms. The questions covered general information about vessel category and length, fishing operations, work experience, work tasks, organisation of work, sick leave and various symptoms, as well as subjective perceptions regarding work environment and health and health-promoting factors. The questionnaire was drawn up by the research team, and a professional polling agency conducted the survey by telephone.

The following questions covered musculoskeletal symptoms: In the previous 12 months, to what degree have you experienced pain in the 1) neck/shoulders/arms, 2) back and 3) knees/hips? The subjects were asked to rate each item on a 5-point scale ranging from a very small to very large degree. Individuals who answered a “large degree” or a “very large degree” were asked if they thought their symptoms were related to their work situation. Questions related to the physical work situation included factors such as repetitive and monotonous work operations, heavy lifting, lifting with the upper body twisted or bent and working with hands at or above shoulder height. The subjects were asked to rate each item on a 5-point scale ranging from very seldom/never to very often. Furthermore, the fishers were asked to rate their self-perceived health on a 5-point scale ranging from very bad to very good.

QUESTIONNAIRE STUDY

Field studies were carried out on board 5 factory trawlers in the Norwegian and Barents Sea [30, 31]. Before fishing commenced, 153 crew members were recruited to participate in the questionnaire study. The mean age of the participants was 40.1 years and 5.2% were women. One hundred and two (67%) crew members were directly engaged in fishing and were fishers, netman, factory manager, foreman, apprentice, while 51 were skipper, mate, chief engineer, engineer, steward or catering personnel.

The 67-item questionnaire covered questions about demography, working conditions, health and work-related health. The following questions were asked: In the previous 12 months, have you experienced stiffness and/or pain from: 1) neck/shoulders, 2) elbow/under arm/hand, 3) lower part of the back, 4) upper part of the back 5) hips/ /thigh/feet? The fishermen were also asked to rate their self-perceived health.

All methods were approved by the Data Protection Official for Research, Norwegian Centre for Research Data or the Regional Research Ethics Committee in Medicine, Norway.

DATA ANALYSES

Statistical analyses used the SPSS statistical package. The outcome variables from the telephone survey and the questionnaire study were determined using descriptive statistics (frequency analyses). Data from the registries were analysed by χ^2 or Student’s t-test, and the significance levels were set to $p < 0.01$ or 0.05, respectively.

RESULTS

REGISTRIES

Analysis of sick-leave provided by NAV showed that fishers had a significantly higher percentage of sickness absence (5.2%) than the age- and gender-matched control group (4.6%) in 2013 [11]. Moreover, MSD were the main cause of sickness absence among fishers (50%), which was significantly higher (t-test, $p < 0.05$) than in the age- and gender-matched control group (45%).

Looking into the ICPC-2 MSD codes in more detail, the fishers were overrepresented compared to the controls in the codes for muscle pain, hand/finger, ankle, muscle symptoms/complaints not otherwise specified (NOS), leg/thigh and jaw, sprained/strained ankle, musculoskeletal injury NOS and hand/foot bone fracture.

Analysis of hospitalisation and outpatient consultation data from the NPR for the period 2008–2013 (average) showed that fishers, compared to the control population, suffered significantly more acute incidents due to musculoskeletal diseases (5.4% vs. 4.8%, respectively), and injuries in arm (11.3% vs. 9.8%), foot (8.4% vs. 8%) and back (0.9% vs. 0.7%).

TELEPHONE SURVEY

In the telephone survey (n = 832), 61% of the respondents reported that they performed monotonous work operations often or very often, while 43% and 42% reported heavy lifting and lifting with the upper body twisted or bent, respectively (Fig. 1). Fishers who reported frequent or very frequent exposure to humid environments, strong winds and cold were 68%, 37% and 40%, respectively. Thirteen per cent reported that they felt cold at work often or very often, while 25% occasionally reported this (Fig. 1).

Thirty-three per cent had experienced pain in the neck/ /shoulders/arms to a considerable or very considerable degree during the previous 12 months, while 19% and 15% had experienced pain in the back and knees/hips, respectively (Fig. 2). Of those who reported health complaints, 82–93% believed these pains were completely or partly due to their work situation. In terms of operating modes, differences were seen between trawl, autoline and coastal vessels. Pain in the neck/shoulders/arms was reported higher among fishers on coastal vessels (42%) compared to trawl (20%) whereas pain in the knees/hips were higher in trawl (23%) than in coastal fishing (16%). Expressed as relative risk (RR), fishers in the coastal fishing fleet have

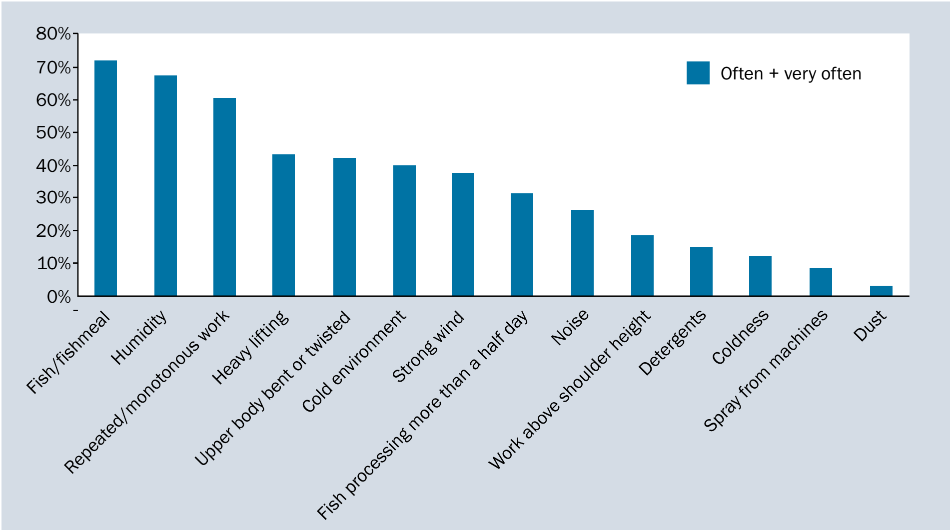

Figure 1. Self-reported exposure in the fishers' work environment (n = 832)

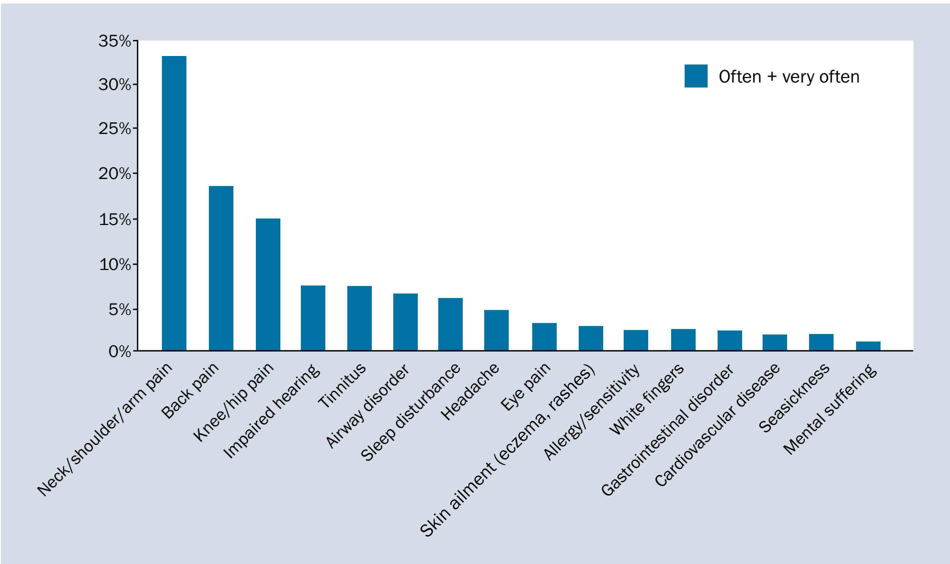

Figure 2. Self-reported health problems among fishers during the previous 12 months (n = 832)

a 1.6 times higher RR of experiencing musculoskeletal pains, while fishers on purse seine boats have a lower RR of experiencing musculoskeletal pains (0.5) compared to other operations [4]. Notwithstanding these pains, 77% of the fishers in all the vessel groups reported their own health as being very good or good.

QUESTIONNAIRE

The questionnaire completed by all crew members of the 5 trawlers (n = 153) showed that 54% and 55% had experienced stiffness and/or pain in the neck/shoulders and lower back/small of the back during the last 12 months, respectively. In the same period, of those 102 directly engaged in fishing, 57% and 60% had experienced such stiffness and/or pain in the neck/shoulders and lower back/small of the back, respectively. Of the fishers who answered in the affirmative to the question about stiffness and/or pain, 62% believed this was fully or partly due to their work situation; whereas 35% of the other crew members reported the same.

All the respondents attributed their complaints to repetitive, monotonous movements (39%), heavy lifting (37%), work at high speed (22%) and work with hands at or over shoulder height (22%). Dividing into subgroups, repetitive, monotonous work was the explanation for complaints among 52% of the fishers and 14% among other crew members. This was followed by heavy lifting (46% fishers vs. 20% other crew members) and working at high speed (30% fishers vs. 6% other crew members).

Seventy-five per cent of all the crew members on the 5 trawlers and 77% of the fishers reported their own health as being very good or good.

DISCUSSION

Our findings from the registries supported our hypothesis that MSD were the main cause of absence due to sickness. Compared to the control population they suffered significantly more acute incidents due to musculoskeletal diseases and injuries to arms, feet and backs. Even though more than two-thirds of the fishers reported their own health as being very good or good, they reported a high incidence of MSD.

In our study monotonous work operations (61%), heavy lifting (43%) and working twisted/bended (42%) were reported often/very often among occupational fishers in the telephone survey and were often the main reasons for the MSD. The self-reported pain in the neck/shoulders/ /arms was fully or partly explained by their work situation by 93% of our sample. Our results are supported by other studies of fishers [6, 32, 33] and similar studies have also shown that perceived workload and musculoskeletal pain are closely linked to the occurrence of MSD [34]. Data from the Danish Working Environment Authority also shows that monotonous work postures and repetitive work increase the risk of developing pain in the musculoskeletal system [35]. Østergaard et al. (2016) [6] found that standing was fishers' most frequent work position, while repetitive hand and finger movements and lumbar twisting and bending were other frequent postures. They also showed that correct lifting techniques are known. However, only about half of the respondents used such techniques at work [33]. Reducing ergonomic exposures associated with work among these occupations is important, regardless of whether they directly cause or contribute to their musculoskeletal symptoms or aggravate existing pathology [5].

The literature regarding physical strain of fishing is sparse [28] but some studies have reported cardiovascular strain of fishers [36–38]. Previous studies based on Norwegian coastal fishing have shown that work on the trawl deck can be characterised as an intermittent activity with average levels of cardiac strain. A newer study of thermophysiological responses and work strain during work on trawl deck [30] showed that workers are periodically exposed to high work strain, manifested as raised core temperature and heart rate when working on the trawl deck. These results show that cardiovascular strain among fishers is moderate to heavy. In our study, repetitive movements, heavy lifting and working at high speed were the most common explanations for MSD. This is in also accordance with Törner et al. (1988) [33], who claimed that symptoms follow a logical pattern according to age, number of years in the fishing industry, type of fishing operation and type of work performed on board, where heavier work-load leads to higher incidence of symptoms/discomfort as well as musculoskeletal problems [33].

Fishing has been reported to be the most hazardous occupation also due to exposure to cold stress and wind [28]. In our study the fishers reported that they often or very often are exposed to unfavourable working conditions such as humid conditions (68%), strong winds (37%) and cold environments (40%). When the data were analysed in terms of "operational groups" the results also showed that coastal fishers are more exposed to climatic, ergonomic, processing (contact with fish/fishmeal, gutting or processing) factors, and are more likely to experience musculoskeletal problems and to take leave of absence from work than fishers in other modes of operation [4]. A Finnish study reported that progressively lower temperatures increase self-reports of musculoskeletal pain [39], and when repetitive work is combined with exposure to cold environments this may also have a negative effect on muscle function and fatigue [20] that may lead to strain injuries and in the long term, to MSD [21]. Several studies have looked at the incidence of work-related MSD arising from cold indoor work, especially in the fish-processing industry [16, 22, 40–44]. Prolonged low-intensity highly repetitive work in a cold environment can mean a higher risk of developing musculoskeletal symptoms among fishers [5, 12, 23].

Although MSD have previously been studied in a wide range of occupational groups, only a few studies have examined this topic among occupational fishers. One strength of our study is its design, which is based on three different methods; National registries and cross-sectional studies including telephone survey and questionnaire. This combination was intended to provide a well-integrated picture of the situation [45]. Another strength of the study is the very large study population of fishers (n = 25,971) acquired from the registries (SSB), which gives a robust dataset. Data from SSB also included an age- and gender-matched control population (n = 77,913), where the ratio of three control subjects per study subject strengthen the reliability of the total dataset. The three methods used in this study included different populations of occupational fishers, and the differences between methods in population size, type of boats, time of the study, wording/framing of the questions may affect the answers. Low response rates are the norm in cross-sectional questionnaire studies of fishers, especially when questionnaires are long, and the presence of a healthy worker effect may influence the findings [6]. Instead of using a questionnaire in written form sent by mail, e-mail or online, we employed telephone interviews that were designed to take 10 minutes, which also helps to quell subjects' doubts about the time spent on participating. Although we do not have any information about the total numbers of fishers called, in other studies we have found that using a telephone survey the response rate tends to be high (61%) [46]. In the questionnaire study on board the deep-sea fishing vessels, 70% of the crew members answered the questionnaire.

CONCLUSIONS

Findings from the registries, telephone survey and questionnaire survey all confirmed that MSD are common among Norwegian occupational fishers and that the problems are closely linked to their work situation. Even so, 77% of both the crews of all the vessel groups and the fishers on the 5 selected trawlers reported their own health as being very good or good. Research and regulation in the Norwegian fishing industry has focussed on acute injuries and fatalities. This study has increased our understanding of environmental challenges and MSD during work and shows that preventative measures as well as technological solutions aimed at reducing strain and exposures related to work are necessary to improve the health of occupational fishers.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

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ORIGINAL ARTICLE

Musculoskeletal complaints among professional divers

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ABSTRACT

Background: *Previous publications have indicated a high risk of musculoskeletal complaints among professional divers. This study aims to investigate which factors influence professional divers' risk of musculoskeletal complaints.*

Materials and methods: *Based on data gathered from a postal questionnaire sent to Norwegian inshore divers in 2011, the prevalence of musculoskeletal complaints, strain injuries and joint pain among divers with different certification levels, work-related tasks and decompression sickness (DCS) experiences were analysed.*

Results: *The risk of musculoskeletal complaints, strain injuries and joint pain was significantly higher among divers working in the quay/construction industry versus divers not working in this industry, and among divers who had experienced DCS. Likewise, a higher risk was found among divers doing construction, inspection, pipelaying, blasting and welding, other physically demanding work, and working with vibrating and/or rotating tools. Having experienced tingling and/or numbness in fingers after working with vibrating and/or rotating tools or having sick leave due to tendonitis, periosteum inflammation, stretch injuries or sprains caused by diving also increased the risk.*

Conclusions: *Professional divers working in the quay/construction industry, divers doing tasks with heavy physical demands and divers having experienced DCS are at a higher risk of musculoskeletal complaints than other professional divers.*

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Key words: demanding work, diving, joint pain, musculoskeletal complaints

INTRODUCTION

Musculoskeletal complaints as part of long term health effects among professional divers have been a topic of research and discussion for the last two decades. A higher prevalence of joint disorders has been found among Unites States (US) military divers compared to nondiving US officers, whereas the non-diving officers were found to have higher hospitalisation rates for stress-related disorders and circulatory disease [1, 2]. In a Norwegian study, former North Sea professional divers reported a reduced health related quality of life compared to the general Norwegian population as measured by the 36-Item Short Form (SF-36). All SF-36 sub-scores, including the subscale rating "bodily pain", were reduced in the diving group. Having experienced decompression sickness (DCS) and high cumulative diving experience contributed to reduced health-related quality of life scores [3]. A study performed in the United Kingdom (UK) found that divers reported more musculoskeletal complaints than offshore workers who did not dive, but these groups did not differ in reported health-related quality of life [4]. Musculoskeletal pain is associated with lower quality of life scores in other workers, such as dockworkers [5]. In the Norwegian population musculoskeletal complaints are highly associated with sick leave [6]. Another study which included a randomly drawn cohort from the general population in Norway where the respondents were in paid work found that highly demanding jobs, neck flexion and awkward lifting appear as the most important predictors of neck/shoulder pain [7].

This study aims to investigate potential risk factors for musculoskeletal complaints in professional divers.

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MATERIALS AND METHODS

Norwegian inshore divers are certified by the Norwegian Labour Inspection Authority, an occupational safety and health agency of the Ministry of Labour. From 1980 onwards, the Labour Inspection Authority has operated the Norwegian Inshore Diver Registry (Diver Registry) which contains data on all divers with a certificate valid for professional inshore diving. The Norwegian Petroleum Safety Authority manages a separate registry for off-shore divers. Those diving both inshore and offshore are recorded in both registries. By August 2010, 7,079 divers were included in the Diver Registry. Altogether 6,138 of these could be identified with their national identification number, providing their home address.

The study "Diver 2011" used a comprehensive questionnaire which was prepared and sent by mail to all identified divers and a stamped return envelope was enclosed. The questionnaire included questions about diving certification level, work situation, health and diving related issues and was posted during spring 2011 [8].

Altogether 284 questionnaires were excluded due to returned to sender twice or not answered because the receiver told he was a non-diver. Of the remaining, 2,848 (48.7%) persons completed the questionnaire.

The analyses of musculoskeletal complaints were based on three sets of questions from the questionnaire. Each set were considered positive if the subject had given a positive answer to at least one of the sub-questions, and negative if the subject had given a negative answer to all.

"Have you during the last 12 months had pain and/or stiffness in muscles and joints, lasting for at least three months?":

- Set 1: This set includes all the questions; neck, upper back, lumbar region, shoulder, elbow, wrist/hand, groin, hip, knee and ankle/foot;
- Set 2: Typical strain; neck, upper back and lumbar region;
- Set 3: Typical joints; shoulder, elbow, wrist/hand, groin, hip, knee and ankle/foot.

Certificates are graded according to qualification: Class S is restricted to scientific diving with SCUBA gear to a maximum depth of 30 m. Class R is restricted to rescue diving to a maximum depth of 30 m. Class 1 requires practical and theoretical training to perform subsea work to a maximum depth of 50 m. Class 2 (closed bell) requires the same training (practical and theoretical) as for Class 1, but in addition the divers are trained and educated in saturation and bell diving. Class 3 requires the same training as Class 1, and in addition practical and theoretical training in specialised subsea work. The qualification range among the certificates are as follows; 2 > 3 > 1 > R, S.

The divers were categorised depending on mainly working in different industries (Quay/construction, Fish farming, Collecting shells, Offshore, Rescue, Photography, Instructor, Research) and doing certain tasks often (positive answer) or seldom/never (negative answer). Potential risk factors like physically demanding work, working with vibrating and/or rotating tools, having experienced tingling and/or numbness in fingers after working with vibrating and/or rotating tools and if the diver had had any sick leave because of tendonitis, periosteum inflammation, stretch injuries or sprains caused by diving were analysed.

When analysing the risk of musculoskeletal complaints by the divers' level of qualification, divers having restricted certification (R and S certificates) were used as references. Divers with reported DCS, with or without paresis, were compared to divers not having experienced DCS or DCS with paresis, respectively. When analysing the various industries and tasks, and the additional risk factors, divers not having worked in the industry, doing the task or have the risk factor under study were used as references.

The divers included in the study had given their written consent and the study was approved by the Regional committee for medical and health research ethics (REC WEST 2010; 02529).

STATISTICAL METHODS

The descriptive statistics are presented as graphs and tables. Quartiles of age was defined as Q1 < 37 years, Q2 = 38–45 years, Q3 = 46–53 years and Q4 > 54 years. Relative risks (RR) of musculoskeletal complaints, strain injury and joint pain were analysed by Generalised Linear Models with binomial distribution and log link. Both crude and adjusted (age, gender, total number of dives and at least one episode of DCS) RR with 95% confidence intervals (CI) were reported. All statistical analyses were performed by IBM SPSS version 22 [IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp].

RESULTS

The study included 2,663 males and 185 females. The median age was 45.0 and 38.0 years, respectively.

Quay/construction and offshore divers reported more often working in: construction work (76.8% and 69.1%), blasting (34.3% and 36.4%), welding (23.5% and 31.6%), physically demanding work (69.6% and 78.5%), work with vibrating/rotating tools (80.1% and 86.2%) than divers in other diving industries (i.e. fish farming: 46.7%, 14.6%, 13.0%, 55.5%, 71.8%).

The prevalence of musculoskeletal complaints increased (Fig. 1) with increasing age. Mean number of dives performed was 1066.3. Divers having performed 1,255 dives or more (the upper quartile) reported more musculoskeletal complaints than those having performed less dives. Having experienced DCS was reported by 469 (16.5%) of the responders.

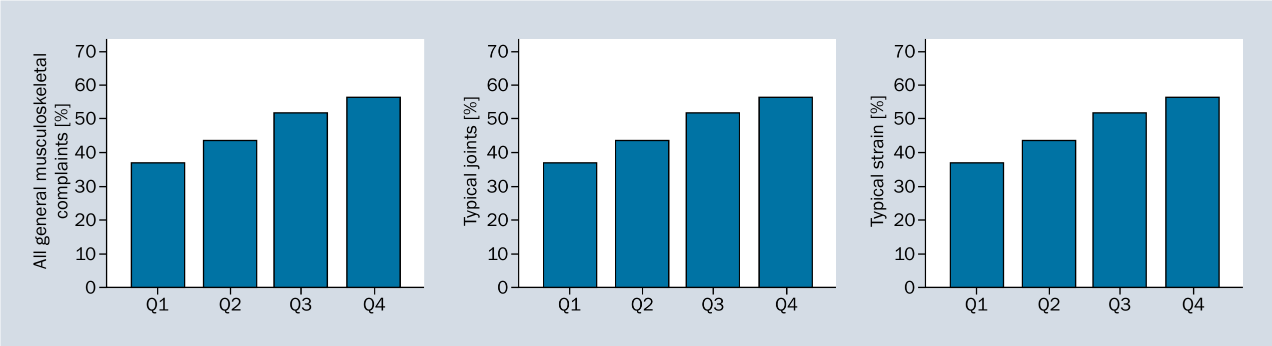

Figure 1. Reported musculoskeletal complaints in age quartiles

Table 1. Musculoskeletal complaints reported in professional divers with different diving certificate

	Certification level	N (%)	Crude RR	95% CI	Adjusted RR*	95% CI
All	R and S (reference)	445 (40.9)	1		1	
	1	364 (53.4)	1.31	**1.18–1.44**	1.11	0.96–1.27
	3	101 (59.8)	1.46	**1.27–1.69**	1.20	**1.04–1.38**
	2	144 (54.8)	1.34	**1.17–1.53**	1.13	**1.02–1.26**
Typical strain injuries	R and S (reference)	311 (28.1)	1		1	
	1	272 (38.6)	1.37	**1.20–1.57**	1.18	**1.03–1.35**
	3	73 (42.7)	1.52	**1.25–1.85**	1.13	0.92–1.39
	2	116 (43.1)	1.53	**1.30–1.81**	1.18	0.99–1.41
Typical joint pains	R and S (reference)	345 (31.2)	1		1	
	1	305 (43.3)	1.39	**1.23–1.57**	1.20	**1.06–1.36**
	3	93 (54.4)	1.74	**1.48–2.05**	1.30	**1.10–1.54**
	2	121 (45.0)	1.44	**1.23–1.69**	1.13	0.96–1.34

*Adjusted for age, gender, total number of dives and decompression sickness; CI — confidence interval; RR — relative risk

MUSCULOSKELETAL COMPLAINTS — GENDER

Male and females reported similar frequency of 'all musculoskeletal complaints' (46.9% vs. 45.9%), strain injuries (34.7% vs. 33.0%), and joint pains (38.6% vs. 35.1%).

MUSCULOSKELETAL COMPLAINTS — CERTIFICATION LEVELS

After adjustments, divers holding certificate level 3 and 2 had increased risk of musculoskeletal complaints compared to divers holding restricted certificates (R or S). Divers holding certificate level 1 had higher risk of typical strain injuries and divers holding certificate level 1 and 3 had a higher risk of typical joint pain (Table 1).

MUSCULOSKELETAL COMPLAINTS — DCS

After adjustments the risks of musculoskeletal complaints, strain injuries and joint pain were higher among divers having experienced DCS with and without paresis (Table 2).

MUSCULOSKELETAL COMPLAINTS — ALL

Working in the quay/construction industry was the only industry associated with a significantly higher risk of musculoskeletal complaints after adjustment. All tasks (construction, inspection, maintenance, laying pipes, blasting, welding) and the potential risk factors (physically demanding work, working with vibrating and/or rotating tools, having experienced tingling and/or numbness in fingers after working with vibrating and/or rotating tools and if the diver had had any sick leave because of tendonitis, periosteum inflammation, stretch injuries or sprains caused by diving) were associated with a significantly higher risk of musculoskeletal complaints after adjustment.

MUSCULOSKELETAL COMPLAINTS — STRAIN

Working in the quay/construction industry was the only industry associated with a significantly higher risk of strain injury after adjustment. All tasks except pipelaying, and all the additional risk factors (physically demanding work,

Table 2. Musculoskeletal complaints reported in professional divers having experienced decompression sickness (DCS)

			N (%)	Crude RR	CI	Adjusted RR*	CI
All	DCS	No	1007 (44.6)	1		1	
		Yes	307 (65.9)	1.47	**1.36–1.60**	1.26	**1.15–1.37**
	DCS with paresis	No	546 (49.5)	1		1	
		Yes	94 (76.4)	1.55	**1.38–1.73**	1.33	**1.18–1.51**
Typical strain injuries	DCS	No	730 (31.9)	1		1	
		Yes	239 (51.0)	1.60	**1.43–1.78**	1.31	**1.16–1.96**
	DCS with paresis	No	404 (36.3)	1		1	
		Yes	85 (68.5)	1.89	**1.64–2.18**	1.62	**1.39–1.89**
Typical joint pains	DCS	No	811 (35.5)	1		1	
		Yes	265 (56.5)	1.59	**1.45–1.75**	1.29	**1.16–1.44**
	DCS with paresis	No	428 (38.5)	1		1	
		Yes	85 (68.5)	1.78	**1.55–2.05**	1.46	**1.26–1.69**

*Adjusted for age, gender and total number of dives; CI — confidence interval; RR — relative risk

working with vibrating and/or rotating tools, having experienced tingling and/or numbness in fingers after working with vibrating and/or rotating tools and if the diver had had any sick leave because of tendonitis, periosteum inflammation, stretch injuries or sprains caused by diving) were, after adjustment, associated with a significantly higher risk of strain injuries than the referents.

MUSCULOSKELETAL COMPLAINTS — JOINTS

Working in the quay/construction industry, fish farming and rescue industry, all tasks listed and all the listed additional risk factors were, after adjustment, associated with a significantly higher risk of joint pain.

Additional statistical analysis was done adjusting for age, gender, total number of dives and *DCS with paresis*. When analysed with this adjustment, the listed additional potential risk factors still were associated with significantly higher risk of all musculoskeletal complaints, strain injuries and joint pain. Also, with this adjustment, divers working in the quay/construction, and doing industry-related tasks (construction, inspection, maintenance, blasting and welding) had higher risk of strain injuries. The subgroup of these divers who also were engaged in pipelaying had a higher risk of joint pain. Divers working as instructors were found to have a significantly lower risk of joint pain after doing this second adjustment. However, the statistic strength of the analysis was weak after doing this second adjustment, and these results are not included in this study.

DISCUSSION

In our study, divers with higher certification levels and the subgroup who worked in the quay/construction industry tended to report musculoskeletal pain, joint pain and strain injuries equally or more often than divers holding a restricted certificate, and especially if they had experienced DCS. The prevalence of these complaints was higher among divers working in the quay/construction industry, and among divers doing demanding industry related tasks. Having experienced tingling and/or numbness in fingers after working with vibrating and/or rotating tools or having sick leave due to tendonitis, periosteum inflammation, stretch injuries or sprains caused by diving also increased risk of musculoskeletal complaints.

This cross-sectional study includes approximately half of the professional inshore diving population in Norway between 1980 and 2011, including both professional divers and divers who mostly dive recreationally (restricted certificates); divers with a great variety in total numbers of dives performed. The questionnaire used included questions related to a variety of diving-related issues and health issues. This gave us a good overview of the divers' health situation, and gave us an opportunity to look specifically into the various industries in which professional divers are employed, and the tasks they perform, to see whether some of them carry higher risk of musculoskeletal complaints than others. Not all divers responded to all questions.

Many divers have been working in more than one industry [9], but we did not differentiate for this in our study. It is likely that several responders had had musculoskeletal complaints in more than one location [10, 11]. Neither did we differentiate between former and current professional divers. Former professional divers have reported less diving related education, higher number of annual and daily dives, more frequent DCS, loss of consciousness while diving and physically demanding dives (diving with much variation in depth, depths deeper than 30 m, bottom time giving more than 15 min decompression time, strenuous dives or being cold/freezing during decompression) [8]. This might have influenced our result since loss of consciousness while diving is shown to have a negative impact on health-related quality of life in former North Sea professional divers [12], and musculoskeletal symptoms are increased for workers in cold environments [13].

The prevalence of musculoskeletal complaints increases with increasing age in the general population [14], and ageing is found to increase the risk of injury during recreational diving and may decrease the divers' recovery potential [15]. In our study, divers with higher age and divers with a high total number of dives had a higher prevalence of musculoskeletal complaints. In the Hordaland Health Studies (HUSK), women were found to have higher risk of musculoskeletal complaints [16]. We did not find a difference in musculoskeletal complaints among male and female divers in our study, which may indicate that female divers are in extraordinary good health or it might be due to the low number of female divers in our data. Having had DCS during the diving career was associated with reduced health related-quality of life (SF-36) subscale `bodily pain´, both compared to the general Norwegian population and to the Norwegian divers not having experienced DCS [3]. In our data, divers having experienced DCS reported musculoskeletal complaints more often.

Overall, 48.5% of the divers in this study reported to have had musculoskeletal complaints lasting at least 3 months during the past 12 months. This prevalence is comparable to the ones found in the Norwegian general population in the Nord-Trøndelag Health Study (HUNT) (51%) [17] and in the HUSK Study (39% of males and 49% of females) [11]. In a previous UK study, a significantly higher proportion of divers reported musculoskeletal symptoms compared to offshore workers (41% vs. 34%) [18]. However, the divers doing the listed tasks were found to have a significantly higher risk of these complaints and the risk tend to be higher than the risk found in the general Norwegian population.

Heavy physical demands at work are associated with musculoskeletal complaints [19–22], which were also shown in our study. Also, psychosocial factors at the workplace are associated with musculoskeletal disorders, in particular when combined with heavy physical demands [23–25]. Psychosocial stress at work was, however, not a part of our study.

Our finding suggests divers having worked with vibration and/or rotating tools are at an increased risk of musculoskeletal complaints, as is also shown for other workers using such equipment [26].

Musculoskeletal complaints are the dominating group of diagnosis leading to sick leave in Norway, constituting 40–50% of total annual cases [6]. Longstanding (> 3 months) symptoms is an independent risk factor shown to double the risk of sick leave [16], and the presence of symptoms can predict sick leave in the following 12 months [27]. Sick leave was strongly associated with musculoskeletal complaints among divers in our study.

In our study, divers working in the quay and construction industry had a higher risk of musculoskeletal complaints, strain injuries and joint pain than other divers, and in general, all the tasks listed also contributed to an increased risk. Tasks like construction, blasting, welding, pipelaying, maintenance are often performed in the quay/construction industry. Construction workers are known to have increased risk of occupational ill health both globally and in Europe [28], and higher risk of musculoskeletal disorders are shown in Germany [29] and in the UK [30, 31]. Welders have an increased risk of musculoskeletal complaints related to heavy physical demands at work [21, 30]. This is also shown to be the case for professional divers working as welders and divers having experienced work related accidents [4] which is similar to our findings.

CONCLUSIONS

Professional divers working in industries with heavy physical demands, such as the quay/construction industry, are at a higher risk of musculoskeletal complaints than professional divers working in other industries. This risk is shared by workers with high physical demands working on land. The data must be interpreted with caution since multiple risk factors, including psychosocial factors at the work place, are likely to be involved, and this study is not designed to show causality. Further research is needed to be done on this issue.

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Fatal and serious injuries on board merchant cargo ships

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ABSTRACT

Background: *Merchant seafaring is one the most dangerous occupation over the world which hosts the physical, ergonomic, chemical, biological, psychological and social elements, which could lead to occupational accidents, injuries and diseases. Therefore, it is a field that should be studied on meticulously and frequently. The aim of this study is to investigate the frequency, circumstances, and causes of occupational accidents on board merchant cargo ships and to identify the risks factors during the daily routine works and dangerous works to be fulfilled.*

Materials and methods: *Data used in this study obtained various occupational accident reports issued by countries' accident investigation units or maritime authorities such as Marine Accident Investigation Branch (MAIB), Marine Safety Investigation Unit (MSIU) and Australian Transport Safety Bureau (ATSB). A total of 331 reports met the inclusion criteria for the 11-year period from 2006 to 2016. Descriptive statistics were given related to data and chi-square analysis was used to test for significant association between categorical variables (seafarer's age, accident type and etc.) and injury severity.*

Results: *Several findings were notable in this study. Ratings (63.5%) were the most affected group suffered from occupational injuries among the crew and the most critical cause of occupational accidents was found the dangerous work practices and ignorance of rules and instructions.*

Conclusions: *Occupational accidents are still crucial concern in maritime industry which imposes a major burden on both seafarers and shipping companies. Reduction in occupational injuries could be achieved by improving the working environment and the quality of life on board, mitigating the mental and physical burden of work and developing policies to encourage the seafarers to obey safety rules and instructions.*

(Int Marit Health 2019; 70, 2: 113–118)

Key words: injury severity, seafarers, merchant cargo ships, occupational risks

INTRODUCTION

Merchant seafarers work in a perilous environment which comprises the physical, ergonomic, chemical, biological, psychological and social elements which could lead to occupational accidents, injuries and diseases [1]. As a result of this dangerous environment, merchant seafarers are exposed to extreme weather conditions [2, 3], hazardous enclosed spaces, noisy mechanical equipment and toxic cargoes [4]. Furthermore, because of the nature of the maritime profession, seafarers face stringent working conditions such as isolation from everyday life, long hours of work, rigid organisational structures and high levels of stress and fatigue [1].

Merchant shipping has, in some countries, fatality rates which are more than 20 times that of the average of the respective country's shore-based industries [5]. According to study of Saarni [6] which comprises Finnish seafarers, the rate of occupational accidents was found close to the rate of for the whole working population in terms of non-fatal injuries. However, there is a lack of statistics in the area of maritime occupational safety and health because of the poor recording and significant differences in data collection methodologies of occupational accidents, incidents and diseases in flag States [1]. Especially, near-accidents, or accidents not causing loss of work-time or sick-leave, are seldom reported from ships [7].

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The aim of this study is to investigate the frequency, circumstances, and causes of occupational accidents on board merchant cargo ships and to identify the risks factors during the daily routine works and dangerous works to be fulfilled. After analysing the main causes and risk factors of the occupational accidents clearly that would be easier to take correct preventive measures.

MATERIALS AND METHODS

Data used in this study obtained various occupational accident reports issued by countries' accident investigation units or maritime authorities such as Marine Accident Investigation Branch (MAIB), Marine Safety Investigation Unit (MSIU) and Australian Transport Safety Bureau (ATSB). Table 1 shows the number of occupational accident reports obtained from each investigation unit or maritime authority. Reports concerning occupational accidents occurred on board merchant cargo ships that has over 500 gross registered tons and over included in this study. Fishing vessels and passenger ships were excluded due to these vessels require quite different work experiences in terms of technical demands [8]. Also, reports related to non-crew members such as passengers, pilots, cargo inspectors and dock workers were left out of scope for this study. A total of 331 reports met the inclusion criteria for the 11-year period from 2006 to 2016. Hong Kong, Malta, Denmark, Germany, Australia and United Kingdom provided 80% of the all accident reports used in this study.

Table 1. Number of occupational accident reports according to preparatory Accident Investigation Unit

Investigation Unit	Country	Number of reports
MARDEP	Hong Kong	77
MSIU	Malta	56
BSU	Germany	40
MAIB	England	36
ATSB	Australia	32
DMAIB	Denmark	24
JTSB	Japan	14
DSB	Holland	10
AIBN	Norway	9
HBMCI	Greece	7
IMMA	Isle of Men	7
SIA	Finland	7
BEAMER	France	3
TAIC	New Zealand	3
TSBC	Canada	3
TBMA	Bahamas	2
PKBWM	Poland	1
Total		**331**

Accidents reports were examined through content analysis in the light of the variables obtained from the literature. Then, variables were divided into three categories as seafarer-related variables, ship-related variables and accident-related variables. Ship-related variables included ship age and ship type. Accident-related variables included occupational accident type, working situation at time of the accident and cause of accident. And, the variables related to the seafarer included seafarer age, experience, rank and time on board spent by seafarer when accident took place. Seafarer ranks were classified as officers and ratings and service crew were included also to ratings category because of scarce reports concerning service crew. Injury severity which grouped into serious injuries and fatal injuries were used as dependent variable to be able to carry out significance tests. According to International Maritime Organisation (IMO) [9], a very serious marine casualty means a marine casualty involving the total loss of the ship or death or severe damage to the environment. A serious injury means an injury sustained by a seafarer, resulting in incapacitation where the seafarer is unable to function normally for more than 72 hours, commencing within 7 days from the data when the injury was suffered. In the light of these definitions, very serious marine casualties which resulted in death of seafarers were accepted as fatal injury. Besides, any fracture, any loss of a limb or part of a limb, loss of sight, whether temporary or permanent and any other injury leading to hypothermia or unconsciousness etc. and slight injuries were evaluated in the context of serious injury.

An occupational accident type means the mode in which a seafarer on board injured. In this context, accident not related to ship operations, illness, suicide and homicide can be regarded as occupational accident type [10]. Some studies which examined occupational mortality at sea [4, 11–16] divided cause of deaths into two categories as deaths from disease and deaths from external causes. Deaths from external causes comprised of accidents, suicide, homicide and unknown circumstances. And accidents which caused deaths at sea examined under three headings as maritime disasters, occupational accidents and off-duty accidents. However, occupational accident types were not used in the analysis or accident type included to study as the cause of accident in the aforementioned studies. Unlike these studies, only included occupational accidents occurred on board ship, while homicide, suicide and maritime disaster caused to death or injury excluded in this study. And, the occupational accidents were classified according to International Labour Organisation (ILO) [17] in terms of accident type (e.g., falls of persons, struck by falling objects and exposure to or contact with harmful substances).

Table 2. Distribution of injuries according to seafarer characteristics

Seafarer's	All cases	Injury severity	
		Serious injury	Fatal injury
Age at time of accident [year]			
≤ 25	30 (9.0%)	12 (40.0%)	18 (60.0%)
26–35	106 (32.0%)	39 (36.8%)	67 (63.2%)
36–45	88 (26.5%)	35 (39.8%)	53 (60.2%)
46–55	60 (18.1%)	19 (31.7%)	41 (68.3%)
≥ 56	47 (14.1%)	16 (34.0%)	31 (66.0%)
Sea experience [year]			
≤ 5	99 (30.0%)	37 (37.4%)	62 (62.6%)
6–10	85 (25.6%)	32 (37.6%)	53 (62.4%)
11–15	50 (15.1%)	24 (48.0%)	26 (52.0%)
16–20	39 (11.7%)	9 (23.1%)	30 (76.9%)
21–25	30 (9.0%)	10 (33.3%)	20 (66.7%)
≥ 26	28 (8.4%)	9 (32.1%)	19 (67.9%)
Time aboard when accident took place [month]			
≤ 3	148 (44.7%)	57 (38.5%)	91 (61.5%)
4–6	140 (42.2%)	53 (37.9%)	87 (62.1%)
7–9	43 (13.0%)	11 (25.6%)	32 (75.4%)
Occupation on board*			
Officers	121 (36.5%)	53 (43.8%)	68 (56.2%)
Ratings	210 (63.5%)	68 (32.4%)	142 (67.6%)
Total	**331**	**121 (36.5%)**	**210 (63.5%)**

*Statistically significant differences assumed at $p < 0.05$

The study employed descriptive statistics to gain an overall understanding of occupational accidents occurred on board ship and chi-square analysis was used to test for significant association between categorial variables (seafarer's age, accident type and etc.) and injury severity. Statistical significance was established at $p < 0.05$.

RESULTS

The study population included 331 seafarer cases of fatal injuries and serious injuries on board merchant cargo ships (Table 2). There were 210 (63.5%) fatal injury cases and 121 (36.5%) serious injury cases. There were no significant differences in rates of injury severity by age, sea experience, and time on board when the accident took place. However, there were significant difference by occupation on board; ratings had significantly higher fatal injury rates compared to officers (56.2% vs. 67.6%, $p = 0.038$). In addition, ratings had two-thirds of the total injuries.

Time on board means the day of the accident from the day the seafarer signed on. Seafarers are signed on the day they arrive on board and the first they are usually used for travel and because of that they have not much time for work on board. In the light of this explanation, it is seen that nine-tenths of the injuries occurred within the first 6 months after the seafarer joined the ship. As aforementioned, although there is no significant relationship between seafarer age and experience with injury severity, 55% of injuries suffered by seafarers who had 10 years or less sea experience.

The highest frequency of occupational accidents was found on bulk carriers, container ships and general cargo ships with 90, 85 and 72 cases, respectively. Also, there were found significant difference between ship type and injury severity ($p = 0.007$). As seen from Table 3, bulk carriers, container ships and general cargo ships had higher fatal injury rate compared to rest of the ship types in this study. However, there was not found significant difference between ship age and injury severity.

In Table 4, occupational accidents classified based on the activity of seafarers at the time of the accident and accident types were shown. Both accident type and working situation at time of accident were found statistically significant ($p = 0.000$, $p = 0.003$, respectively). Especially, injuries took place as a result of falling from height or falling overboard had remarkable fatality rate (75.2%) and alone accounted for 42.5% of the total injuries. Another accident type that had high fatality rate was exposure to or contact

Table 3. Distribution of injuries according to ship characteristics

Ship's	All cases	Injury severity	
		Serious injury	Fatal injury
Age [year]			
≤ 5	98 (29.6%)	43 (43.9%)	55 (56.1%)
6–10	75 (22.6%)	24 (32.0%)	51 (68.0%)
11–15	56 (16.9%)	17 (30.4%)	39 (69.6%)
16–20	39 (11.7%)	9 (23.1%)	30 (76.9%)
≥ 21	63 (19.0%)	28 (44.4%)	35 (55.6%)
Type*			
Oil/chemical tanker	36 (10.8%)	16 (44.4%)	20 (55.6%)
Bulk carrier	90 (27.1%)	27 (30.0%)	63 (70.0%)
Container ship	85 (25.6%)	26 (30.6%)	59 (69.4%)
General cargo ship	72 (21.7%)	24 (33.3%)	48 (66.7%)
Product tanker	14 (4.2%)	6 (42.9%)	8 (57.1%)
Others	34 (10.2%)	22 (64.7%)	12 (35.3%)

*Statistically significant differences assumed at $p < 0.05$

Table 4. Distribution of injuries according to occupational accident characteristics

	All cases	Injury severity	
		Serious injury	Fatal injury
Accident type*			
Falls from height/falls overboard	141 (42.5%)	35 (24.8%)	106 (75.2%)
Struck by rope or chain	46 (13.8%)	18 (39.1%)	28 (60.9%)
Caught or in between objects	46 (13.8%)	24 (52.2%)	22 (47.8%)
Exposure to or contact with extreme temperatures electric current	34 (10.2%)	19 (55.9%)	15 (44.1%)
Exposure to or contact with harmful substances/asphyxiation	42 (12.6%)	16 (38.1%)	26 (61.9%)
Struck by falling objects	10 (3.0%)	7 (70.0%)	3 (30.0%)
Slips, stumbles and falls	12 (3.6%)	2 (16.7%)	10 (83.3%)
Working situation at time of accident*			
Cleaning in tank/hold	28 (8.4%)	9 (32.1%)	19 (67.9%)
Entrance to enclosed spaces	36 (10.8%)	7 (26.9%)	19 ((73.1%)
Loading/unloading cargo	67 (20.2%)	25 (37.3%)	42 (62.37%)
Maintenance and repair at engine department	33 (10.0%)	17 (51.5%)	16 (48.5%)
Maintenance on deck	66 (20.0%)	22 (33.3%)	44 (66.7%)
Mooring operations	40 (12.0%)	17 (42.5%)	23 (57.5%)
Rigging and taking in gangways and ladders	18 (5.4%)	2 (11.1%)	16 (88.9%)
Ship drills	34 (10.2%)	20 (58.8%)	14 (41.2%)
Walking from one place to another	19 (5.7%)	2 (10.5%)	17 (89.5%)

*Statistically significant differences assumed at $p < 0.05$

with harmful substances and asphyxiation (61.9%) which occurred mostly during the entrance to enclosed spaces and cleaning in tank/hold on board ship. The most frequent work situations at the time of the accident were maintenance on deck (44 fatalities and 22 serious injuries) and duties fulfilled during the loading and unloading cargo operations (42 fatalities and 25 serious injuries). Furthermore, these two work situations accounted for 40% of total injuries with high fatal injury rates with 66.7% and 62.3%, respectively.

Table 5. Main causes and contributing factors of occupational accidents on board ships

Causes	N (%)
Dangerous work practices and ignorance of rules and instructions	176 (53.2%)
Insufficient risk assessment or hazard identification	49 (19.8%)
Machine/equipment malfunction	37 (11.2%)
Unsafe working environment and adverse weather condition	24 (7.3%)
Lack of education, experience and training	21 (6.3%)
Lack of communication and team work	12 (3.6%)
Deficiencies in instruction and guidance	12 (3.6%)

The most common causal factors that led to occupational accidents were examined in seven categories which were obtained from occupational accident reports (Table 5). Dangerous work practices and ignorance of rules and instructions (53.2%) was found the most common cause of accident (e.g., working in an inappropriate place on board, not using personal protective equipment, dangerous work habits, negligence of snap back zones). Other common factors contributing to the injuries were insufficient risk assessment and hazard identification (19.8%), machine/ /equipment malfunction (11.2%), inappropriate education, experience and training and unsafe working environment (e.g., rough weather, poor illumination, insufficient ventilation) and lack of communication and team work.

DISCUSSION

Several findings were notable in this study. Ratings (63.5%) were the most affected group suffering from occupational injuries among the crew. This finding is consistent with other international studies that have identified the ratings as having the highest risk of on-duty accidents [4, 13, 15, 18–20]. Similarly, recent studies stated that accidents are generally more frequent among non-officers compared with officers [21, 22]. The reasons of the high risk of occupational injury among ratings are compelling working environment and dangerous works fulfilled on board ship [23].

While the aging seafarer workforce remains an increasing concern [24], our study did not find a significant relationship between seafarer age and injury severity. This is consistent with the study of Lefkowitz et al. [25] who tried to explore risk factors for merchant seafarer repatriation due to injury and illness. On the other hand, Hansen et al. [26] studied on Danish merchant vessels and found the age of seafarer as a contributing risk factor for injury-related disability. Similarly, study of Lefkowitz et al. [27] revealed that higher age is significant risk for work restriction.

Falls on board or falls overboard merchant ships caused almost 42% of the occupational accidents which is the same as reported by Roberts and Marlow [19] for seafarers employed in British merchant shipping. Seafarers largely experienced falls into or inside holds during cargo operations, off ladders or down stairways, falls from heights while working at the ship's side for painting or cleaning, and falls overboard when rigging or de-rigging gangways and pilot ladders. Fatalities and serious injuries through falls overboard or fall on board can substantially be prevented by the more widespread use of self-inflating life vests or safety harnesses when engaged in potentially hazardous operations at great heights or along the sides of ships.

Asphyxiation and exposure to harmful substances in enclosed spaces (12.9%) during entry in holds and tanks for cleaning cargo residue, maintenance and routine inspection have also been reported as one of the most common type of occupational accident among seafarers, which is consistent with other studies [4, 12, 13, 18–20]. Hansen [28] pointed that oxygen contents in enclosed spaces were not properly checked and safety lines were not rigged which caused to delay the rescue. Prevention of enclosed space accidents can be achieved through adherence to recommended procedures and checklists when entering enclosed spaces, which have been extended progressively over time in shipping [29].

Being struck by mooring or towing ropes and chain of anchor during the mooring and anchoring operations is one type of occupational accident causing fatal and serious injuries among seafarers. Hazards often appear when the ropes become tense due to sudden unpredictable ship movements, use of worn ropes/wires and negligence of snap back zones. Also, weak communication among the crew and between ship and shore personnel was one of the main causes of mooring accidents. These types of accident can be avoided by maintenance and replacement of worn ropes regularly and abstaining from standing in proximity to ropes under stress. Besides, before planning the mooring and anchoring operations, considering the weather condition factors such as wind and current is crucial for prevention of unforeseeable ship movements.

The most critical cause of occupational accidents was found the dangerous work practices and ignorance of rules and instructions (e.g., not using personal protective equipment, dangerous work habits, and negligence of snap back zones) in this study. In the studies of Oldenburg et al. [14] and Uğurlu et al. [30], it was also found that lack of using or improper use of personal protective equipment was the primary causal factor leading to fatalities or serious injuries. Also, insufficient risk assessment or hazard identification deficiencies in instruction or guidance, machine/equipment malfunction and inappropriate education, experience and training were the other main causes of occupational accidents on board merchant cargo ships.

CONCLUSIONS

Occupational accidents are still crucial concern in maritime industry which imposes a major burden on both seafarers and shipping companies. However, our study showed that injuries frequently resulted from human error such as dangerous work practices and ignorance of rules and instructions. Reduction in occupational injuries could be achieved by improving the working environment and the quality of life on board, mitigating the mental and physical burden of work and developing policies to encourage the seafarers to obey safety rules and instructions.

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VIA MEDICA

ORIGINAL ARTICLE

Evolution of the respiratory function of professional divers over 15 years

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ABSTRACT

Background: *The study was aimed at assessing changes in respiratory function after 15 years of professional diving, among scientific divers.*

Materials and methods: *A retrospective study was performed on divers who underwent an initial visit and a visit 15 years later at the same medical centre, among divers who had a scientific activity (monitoring the coastline, fauna and flora). Pulmonary function tests were performed in the same laboratory with the same operating standards and using a Jaeger MasterBody plethysmograph. Each subject acted as his or her own control. The data were analysed by Student's t-test and Spearman's correlation coefficient.*

Results: *Twenty-six divers were included. Changes over 15 years included: a decrease in the forced expired volume in 1 second/functional vital capacity (FEV1/FVC) ratio (–6 for absolute value, $p < 0.01$; and –5% for theoretical value, $p = 0.02$); a decrease in forced expiratory flow $(FEF)_{25\%}$ (–1.1 for absolute value, $p < 0.01$; and –21% for theoretical value, $p < 0.01$); a decrease in transfer factor for carbon monoxide (TLCO) (–0.7 for absolute value, $p = 0.04$); and an increase in vital capacity (VC) (+8% for theoretical value, $p = 0.03$). A significant correlation was found between the consumption of tobacco in packs per year (PY) and the variations in VC ($r = 0.89$; $p < 0.01$) and the variations in the theoretical FEV1 ($r = 0.76$; $p = 0.03$). There was a significant relationship between the number of dives and the variations in the percentage of the theoretical FEV1/FVC ratio ($r = –0.42$; $p = 0.04$). The same relationship was found for the average of dive duration ($r = –0.59$; $p < 0.01$)*

Conclusions: *With increasing length of diving activities service, the pulmonary function displays a trend toward both a decrease in TLCO and a decrease in $FEF_{25\%}$.*

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Key words: diving/physiology, pulmonary ventilation/physiology, occupational exposure, retrospective study

INTRODUCTION

The impact of professional diving on respiratory function has been studied for several decades. The data are often contradictory from one study to another. The populations do not always have a homogeneous exposure, or some articles relate to selected populations (like military divers) which produces a healthy workers effect. This article brings a new light because the population is not selected for its particular physiological capacities. These are scientists who dive for their studies. This highlights the effects of this occupational exposure.

The exercise of professional diving involves a variety of different activities [1]. Some divers are scientists, diving to collect information on fauna, flora, the chemical environment, etc. Other divers are responsible for monitoring human activities, such as coast guards or the gendarmerie. Still others are military and do demining or combat missions. The physical constraints are not the same, and gas mixtures

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can vary according to dive profiles. All these divers, however, are exposed to factors that may influence their lung function, such as hyperoxia, compression and decompression phenomena [2, 3].

These constraints could lead to deleterious effects on lung function. On this hypothesis, existing studies propose divergent results [1, 4]. For some authors, the long-term effects could be the appearance of a small airway disease [5, 6]. Other studies have shown variations in bronchial flow [7–9]. In contrast, other studies have shown a lack of effect of long-term professional diving on respiratory function [10]. However, studies for which there were no long-term effects often involved populations of military divers. Tetzlaff et al. [10] showed in 2005 that there was no significant effect, which was confirmed by Voortman et al. [11] in 2016. According to these authors, variations in lung capacity are due not to diving, but rather to age.

In France, previous studies have shown a decrease in diffusion lung capacity for carbon monoxide (DLCO) after 5 years of diving and peripheral bronchial discharges (DEM25 and DEM50) after 10 years, taking into account variations due to age and weight [12, 13]. These were studies of professional civilian divers, often scientists. The dive profiles and professional skill requirements were not comparable with the data from the military studies. The purpose of our study was therefore to evaluate the evolution of the respiratory function of scientifically-oriented civil divers over 15 years, taking into account changes related to age and weight variations.

MATERIALS AND METHODS

A retrospective study was carried out based on the files of 339 professional divers being followed at the Consulting Centre for Environmental, Maritime and Professional Pathologies at the Brest (France) University Hospital. We included those divers who had had an initial examination (i.e. before starting the training for professional diving) or at least the first-year examination and the 15-year examination at our Centre, and who dived for scientifically-oriented dives. So exclusion criteria were: been a military or no scientifically divers; and been a diver, who hadn't been followed in this centre for 15 years.

Biometric data, age, past medical history, medications, lifestyle (physical activities, smoking), and diving characteristics (average annual number of dives, mean and maximum depths, mean and maximum dive times, other professional exposure if any) were collected. Smoking consumption was calculated in number of packs per year (PY).

The pulmonary function data at 0 and 15 years were collected. The pulmonary function tests (PFTs) were all collected in the morning, at the same laboratory of the University Hospital. The equipment was a Jaeger Master-Body plethysmograph, calibrated every day and operated by well-trained technicians, with the same procedures over the duration of the study. The PFT included a complete plethysmography and a measurement of transfer factor for carbon monoxide (TLCO), using the breath-holding method. Functional vital capacity (FVC), forced expired volume in 1 second (FEV1), and forced expiratory flows (FEF) at 25% and 50% and 75% of FVC expired (respectively FEF25 and FEF50 and FEF75) were collected; static volumes, in particular total lung capacity (TLC) and vital capacity (VC), were measured by plethysmography, and the FEV1/FVC ratio was then calculated. The values of these parameters were expressed as a percentage of the theoretical value.

STATISTICAL ANALYSIS

The data were collected using Excel® software. Averages and extreme values were determined for each of them. The values at 0 and 15 years were compared to each other and then with the theoretical values in accordance with the values of the European Respiratory Society (ERS) [14–16]. Then Biostatgv® software was used to calculate medians, Student's t-test, and Spearman correlation coefficient.

RESULTS

Twenty-six divers were included in the cohort: 1 (4%) woman and 25 (96%) men. Median age after 15 years of diving was 48.5 years (full range was 39–65 years). Eleven (42%) had medical history at the end of the follow-up: 3 had traumatologic history, 2 had allergies, 1 had gastroesophageal reflux (GOR), 1 had sinusitis, 1 had high blood pressure (HBP) and 1 had anxiety. Only 3 divers had treatments: 1 for anxiety, 1 for HBP, and 1 for GOR.

Ten (38%) divers were current smokers during the 15 years of the follow-up; median consumption was 6 PY (full range was 5–26 PY). Nineteen (73%) divers practiced sport at least once a week: 17 (65%) practiced ground endurance sport (cycling, jogging, etc.) and 2 (8%) did water sports (swimming, windsurfing, etc.). Half (50%) of the divers had been recreational divers before turning professional, but only 8 (31%) practiced recreational diving after becoming a professional diver. Dive profiles were variable (Table 1).

Pulmonary function test carried out at 0 and 15 years showed a progressive decrease in FEF25 in absolute value and compared to theoretical values (Table 2). At the time of the initial examination, 8 (31%) and 10 (35%) divers, respectively, had a FEF25 lower than 70% and 80% of the theoretical value. These numbers were 17 (65%) and 21 (81%) at 15 years. The FEV1/FVC ratio expressed as a percentage of the theoretical value changed at 15 years ($p = 0.02$), but no diver had a FEV1/FVC ratio lower than 80% of the theoretical value over the period of study.

Plethysmography showed a significant increase in VC compared to the theoretical value after 15 years of diving (Table 3). TLC scores were all higher than 80%. They were higher than 120% initially for 6 (23%) divers at 15 years. Absolute values of TLCO decreased significantly after 15 years, but not in comparison with theoretical values (Table 3).

Table 1. Professional dive profiles

Parameters	Mean	Limit values
Number of professional dives per year	68	5–250
Total number of dives over 15 years	1,003	30–3,250
Mean depth [m]	14	4–25
Maximum depth [m]	29	8–60
Mean dive time [min]	60	15–180
Maximum dive time [min]	90	20–180
Total time [min]	79,625	600–585,000

A significant correlation was found between the consumption of tobacco in PY and the variations in VC (B = 0.89; p < 0.01) and also between the consumption of tobacco in PY and the variations in the theoretical FEV1 (B = 0.76; p = 0.03). However, there was no correlation between smoking and the variations in the other data, particularly the decreases in TLCO (p = 0.30), FEF25 (p = 0.79) and FEF50 (p = 0.72).

There was a significant relationship between the number of dives and the variations in the percentage of the theoretical FEV1/FVC ratio: the higher the number of dives, the greater the reduction in the percentage of the theoretical FEV1/FVC ratio (B = –0.42; p = 0.04). The same relationship was found for the average of dive duration (B = –0.59; p < 0.01). Conversely, the maximum duration of the dives did not influence the variations in the PFT.

DISCUSSION

This study of the respiratory function of professional divers employed in the civilian research field showed that

Table 2. Evolution of the various expiratory parameters

Parameters	Initial value Mean (extreme values)	After 15 years Mean (extreme values)	15-year evolution Mean (extreme values)	P
FVC [L]	5.7 (3.2–7.6)	5.4 (3.4–6.8)	–0.3 (–0.8, +0.2)	0.20
Theoretical FVC [%]	116% (82–142)	120% (93–142)	+3.7 (–11, +20)	0.30
FEV1 [L]	4.5 (2.9–5.8)	4.1 (2.7–5.2)	–0.4 (–1.1, +0.2)	0.03
Theoretical FEV1 [%]	112% (82–129)	113% (91–141)	+1.2% (–16, +21)	0.69
Theoretical FEV1/FVC ratio	81 (73–94)	76 (62–87)	–6 (–22, +8)	< 0.001
Theoretical FEV1/FVC ratio [%]	101% (92–119)	96% (82–109)	–5% (–15, +8)	0.02
FEF25 [L/s]	2.3 (1.6–2.9)	1.4 (0.4–3.0)	–1.1 (–1.6,+0.3)	< 0.001
Theoretical FEF25 [%]	88% (40–152)	67% (37–144)	–21% (–98, +54)	< 0.001
FEF50 [L/s]	5.1 (2.6–7.8)	4.4 (1.9–8.5)	–1.0 (–2.2, +0.44)	0.07
Theoretical FEF50 [%]	102% (61–185)	92% (57–175)	–11% (–49, +15)	0.12
FEF75 [L/s]	9.1 (6.5–12.5)	8.6 (4.8–12.8)	–0.9 (–4, +2.5)	0.26
Theoretical FEF75 [%]	114% (90–157)	111% (73–165)	–7% (–45, +20)	0.62

Abbreviations — see text

Table 3. Evolution of the different parameters of static volumes (plethysmography) and of transfer factor for carbon monoxide (TLCO)

Parameters	Initial value Mean (extreme values)	After 15 years Mean (extreme values)	15-year evolution Mean (extreme values)	p
VC [L]	5.6 (3.2–7.6)	5.5 (3.5–7.1)	–0.1 (–0.8, +0.4)	0.60
Theoretical VC [%]	111% (82–134)	118% (97–142)	+8% (–10, +22)	0.03
TLC [L]	7.5 (4.3–10)	7.5 (5.1–10)	0 (–1.0, +1.5)	0.96
Theoretical TLC [%]	106% (80–123)	108% (86–125)	–0.3% (–25, +20)	0.83
TLCO [mmol/min/kPa]	10.1 (6.7–12.5)	9.1 (6.5–11.9)	–0.7 (–1.7, +1.1)	0.04
Theoretical TLCO [%]	94% (74–120)	88% (66–115)	–6% (–28, +14)	0.08

TLC — total lung capacity; VC — vital capacity after 15 years of evolution, PFT are relatively stable and normal. There were significant variations in the degree of deviation from the theoretical values: decrease in FEV1/FVC and FEF25, increase in VC.

Some parameters influence lung volumes, including sex, age, and weight. But in this study, divers could have had changes in weight over a 15-year period. To evaluate the impact of diving and not those of weight or age, a decision was made to compare the results with an unexposed population having the same characteristics of sex, age, weight and sex. Hence the comparison with the reference values of the European Respiratory Society (ERS), which take into account these three parameters. These apply well to Caucasians, between 18 and 70 years old, of average height (between 155 and 195 cm for men and 145 to 180 cm for women). The group studied here corresponded perfectly to these criteria [17]. Theoretical values are often criticised as averages. For certain parameters, subjects might be considered normal or abnormal, whereas in reality they are simply people with larger or smaller sizes. For example, people of small size may have flows that are considered abnormally low. In this study, this problem was avoided: subjects were the same size at baseline and 15 years later; only deviations from theoretical values were compared. It can therefore be concluded that the variations in the differences with the theoretical values, initially and at 15 years, were not due to one of these three parameters. In particular, when a value decreased significantly from the theoretical values, age was not the cause.

However, dive causality cannot be concluded based solely on this data. Other parameters influence variations in lung volumes or bronchial flow, such as diet or physical activity, or environmental pollution. In this study, divers were not exposed professionally to chemical or physical harm to the lungs and bronchi. There was no connection with whether subjects participated in sports or not. It would seem, therefore, that diving is the causal parameter of these variations in relation to the reference values. It is appropriate to moderate the hypothesis because of the weakness of this study, namely co-exposures. There was no investigation of environmental exposure outside of work. Some divers may have been in contact with environmental pollutants. Another shortcoming is related to physical activity, which was tracked over 15 years in medical records, avoiding memory bias. However, the physical activity items were only declarative; classification bias may have occurred in the quantification of physical activity. This study may have underestimated the effects of physical activity or environmental impact other than diving. The choice of divers whose profession was both civilian and scientific in nature should have made it possible to have comparable dive profiles. However, divers had very different activities depending on their studies or their tasks on fauna and flora. This did not make homogeneous exposure groups possible.

In addition, the number of divers monitored over 15 years is relatively low. Other studies have collected data from larger populations. For example, Voortman et al. [11] studied 1,260 Dutch military divers, 103 of whom had been diving for 15 years. Similarly, Sames *et al.* [18] studied the evolution of spirometry in 232 divers for 10 to 25 years. The weakness of our sample did not allow for powerful statistical tests. There could also be a cluster effect on such a small population. Therefore, these results should be confirmed on a larger sample. Our centre follows a large number of divers, but only divers who have done all of their follow-up in this centre were included in this study. This made it possible to have PFT results done in the same laboratory. The purpose of the study was indeed to evaluate the evolution of respiratory function. For this, it was necessary to integrate the spirometry, plethysmography and alveolar-capillary diffusion data, unlike many studies that have only taken spirometry into account. Since these tests required special skills, the choice of a follow-up in the same centre made it possible to collect reliable and comparable data. A future study could include divers who have been followed in our centre for more than 15 years and recover the PFT done in their careers in other centres. Although less relevant from the point of view of the PFT technique, such an approach would make it possible to analyse the evolution of a larger population and to reduce the risk of cluster effects.

These results supported those of previous studies with respect to increasing lung volumes. In the most recent studies, FCV has been shown to increase significantly after 3 or more years of professional diving [7, 11, 19]. Although the oldest studies showed a reduction, it is generally accepted that VC and FVC increase due to the divers' training [1, 18]. For this study, there was no connection with physical activity in general or with diving. The effect of training could be put forward in a future study if data about the type of training were included.

Similarly, the decrease in peripheral bronchial flow rates had already been described in other studies. The significant decrease in FEF25 at 5 years confirms the results of many studies [6, 9, 12, 13, 20, 21]. No significant relation between the decrease in FEF25 and smoking habits was found. Since our subjects had no other professional toxic exposure, we may conclude that this flow reduction derives from the diving experience, suggesting an effect on first the bronchioles and then the larger bronchi. The hypothesis of small airways disease in professional divers has been discussed for several decades [1]. Some studies have shown the appearance of small airways disease among recreational divers [22], but these results have not been systematically shown in all studies for professional divers. There is really no evidence in basic biology to explain these results. One study using high computed tomography of the chest showed minor lobular air trapping, but there was no difference between divers and non-divers. Peripheral flows are rarely studied. Skogstad and Skare [7] showed a decrease in FEF25–75 after 12 years of evolution. In their more homogeneous group, this reduction was correlated with the total number of dives. It is difficult to conclude whether this decrease is relevant. This data has little effect on the clinical condition of the divers. But it seems that it is useful to follow this parameter. Tezlaff et al. [23] showed that expiratory flows at low pulmonary volumes are one of risk factors of pulmonary barotraumas [1, 23–25].

Unlike the most recent data in the literature, there were significant variations in peripheral flows and VC in this study. It is not possible to compare with studies that are simply based on spirometry, because they have no data on plethysmography and FEF25 [11, 18]. The populations were not comparable with that of Voortman et al. [11], for which no variation was found. Their military population included the healthy work bias, well described by the authors. It must also be emphasized that the military has professional aptitude criteria that are not comparable with the civilian population. The divers in this study were all civilians. There was therefore some tolerance for variations in their state of health and compatibility with their occupation. This study therefore had the advantage of showing the evolution of PFT in a dive population subject to a less drastic medical selection. Moreover, unlike data on recreational diving, the subjects of this study were not necessarily interested in diving for the sake of diving. Their dives were based on professional requirements. This difference with the data on recreational diving is considerable: in recreational diving there is a selection effect based on pleasure. Civilian professional divers did not correspond with these other two population types. The data from this study may have shown changes in lung function that were masked by these selections in military and recreational diving studies.

CONCLUSIONS

This study of civilian professional divers showed an evolution in PFT over 15 years. The analyses were done by comparing the deviations from the European theoretical values. There was a significant decrease in FEV1/FVC, FEF25, and an increase in VC. These data are to be weighted against the small size of the population, which included only 26 divers. A complementary study should make it possible to better identify the effects of diving on this particular population. The exposure and selection of these divers was indeed special in that, being scientists, their professional activity included other tasks. Medical selection was thus less drastic than in studies focusing on military divers.

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ORIGINAL ARTICLE

Lung function change in hyperbaric chamber inside attendants

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ABSTRACT

Background: *Hyperbaric oxygen therapy is one of new trends of additional treatment, especially for non-diving-related diseases in Thailand. Hyperbaric inside attendants have to work under hyperbaric environment to provide medical care for patients in the hyperbaric chamber. This study aims to investigate longitudinal change in lung function in hyperbaric inside attendants (HIAs) and the relationship with hyperbaric exposure.*

Materials and methods: *This is a retrospective longitudinal study exploring the adverse long-term effects to the lungs in HIAs. All inside attendants (HIAs) who worked in the public hospitals or medical centres with multiplace hyperbaric chamber in Thailand were included. To be considered for inclusion in the study, inside attendants were required to have at least two follow-up lung function tests and minimum 1-year interval at baseline from annually periodic examination. Lung function of HIAs were compared against reference values of the Thai population.*

Results: *There were 51 subjects with 9.26-year mean period of follow-up. The HIAs showed a significantly decrease in measured lung function in average forced expiratory volume in 1 second (FEV_1), forced expiratory flow at 25–75% of functional vital capacity ($FEF_{25-75\%}$) and FEV_1/FVC ratio over time. The annual reductions in FEV_1, $FEF_{25-75\%}$ and FEV_1/FVC ratio were 22.52 mL per year, 44.92 mL/s per year and 0.48% per year, respectively. The study showed significant differences in annual changes in FVC, $FEF_{25-75\%}$ and FEV_1/FVC ratio between HIAs and the lung function predicted values for the Thais. However, the results revealed no differences of annual change in FEV_1 from predicted values. The average working depths, average session duration and total working hours as HIAs were related with the changes of lung function.*

Conclusions: *Working in a hyperbaric environment does affect the lung function of HIAs. In addition to fitness to work implementation, periodic lung function evaluation should be encouraged to monitor further possible harm to the attendants.*

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Key words: lung function, pulmonary function, hyperbaric inside attendant, hyperbaric chambers, hyperbaric attendant

INTRODUCTION

Hyperbaric oxygen therapy (HBOT) treatment is a procedure performed inside a pressurised chamber (the Hyperbaric Chamber). The patient is placed inside the chamber and the internal pressure is increased to a specific treatment level above 1 absolute atmospheric pressure The patient breathes 100% oxygen for the duration of the treatment.

While most commonly associated with diving-related conditions, HBOT is also an effective treatment in a number of non-diving related conditions such as delayed radiation injury (soft tissue and bone necrosis) and arterial insufficiencies. In Thailand, HBOT is becoming an increasingly common method of treatment for such conditions.

The hyperbaric chamber can be categorised in two types, the monoplace hyperbaric chamber and the multiplace

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hyperbaric chamber. With the multiplace hyperbaric chamber, a hyperbaric inside attendant (HIA) is stationed inside the chamber to provide medical care for patients and take action in case of emergencies during treatment.

Although the HIA is inside the hyperbaric chamber, they do not breathe 100% oxygen like the patients. They breathe the pressurised air within the chamber and therefore have the potential to experience decompression sickness and the associated harmful effects that can have on the various organs and systems of the body. Exposure to the hyperbaric environment also challenges pulmonary function beyond normal physiology. HIAs are exposed to an increased partial pressure of oxygen and the risk of gas microemboli forming during their session in the hyperbaric chamber. High oxygen partial pressure exposure may increase the oxidative stress, inducing inflammatory processes within the respiratory system [1]. During decompression, gas microemboli released from nitrogen saturated tissues are transferred to the lungs to be eliminated by exhalation. These microemboli can cause pulmonary microvasculature inflammation, gas exchange impairment and transient pulmonary hypertension [2, 3]. During breathing compressed air in the hyperbaric environment, the effort of breathing and airway resistance will increase, while lung compliance will decrease. These may affect the respiratory function, especially airway function [4, 5]. Airway obstruction is a relative contraindication for working in pressurised environments because pulmonary over inflation syndrome caused by pulmonary barotrauma is a serious, potentially fatal condition if it occurs during decompression. Therefore, healthy pulmonary function is one of the important elements for HIAs to be declared fit for duty.

In Thailand, Navy divers and HIAs are required to have pre-placement and annual periodic examinations, which include spirometry to detect any abnormality in lung function, in order to ensure that they are fit to work. Currently, there is only one study on lung function change in HIAs [6] and a few studies involving commercial divers [7–21], all with inconclusive patterns of lung function change in these populations. This study aims to investigate longitudinal change on lung function in HIAs in Thailand from the outset of their careers until present day, and with relation to hyperbaric exposure.

MATERIALS AND METHODS

This is a retrospective longitudinal study on lung function change in HIAs. The total number of HIAs who had worked in facilities with multiplace hyperbaric chambers in public hospitals in Thailand is 63. The group consisted of 20 HIAs from Underwater and Aviation Medicine Division, Naval Medical Department, Royal Thai Navy, 8 HIAs from Centre of Hyperbaric Medicine, Somdech Phra Pinklao Hospital, 12 HIAs from Underwater and Hyperbaric Medical Centre, Queen Sirikit Naval Hospital, 17 HIAs from Underwater and Aviation Medicine Division, Abhakornkiatiwong Hospital and 6 HIAs from Division of Underwater and Hyperbaric Medicine, Vachiraphuket Hospital.

The inclusion criteria were HIAs who were at least 20 years old at the start of their careers, had a minimum of 1-year practical experience as an HIA and who had a pre-placement Pulmonary Function Test (PFT), as well as at least one follow up PFT performed at least 12 months later. HIAs meeting these criteria were eligible for inclusion regardless of whether they were still actively working, were no longer employed as HIAs or were retired.

Spirometric data, age and height from each examination were collected from the medical records of HIAs who attended for pre-service and annual medical examinations. The data collection range covered the period from beginning their career as an HIA up until June 30, 2018. Data was collected at the assigned medical centre consisting of the Underwater and Aviation Medicine Division, Naval Medical Department, the Underwater and Aviation Medicine Division, Abhakornkiatiwong Hospital and the Vachiraphuket Hospital.

The HIAs' age and height were recorded, and spirometry was performed at the medical centres. HIAs were required to have a pre-service examination and an annual medical assessment to be declared "fit to work" in a hyperbaric chamber. Pre-service spirometry was collected as a baseline value. Annual spirometry was recorded in the record form. Spirometry was performed according to standard operating procedure by certified technicians. The spirometer was regularly calibrated before use, in accordance with the manufacturers' recommendations.

Hyperbaric inside attendants completed an anonymous questionnaire providing their information at the date of answering the questionnaire on current workplace, age, height, weight, smoking history, medical history, underwater activities (recreational diving and operational diving history) and work experience in hyperbaric chambers (total years of working, total number of working, average working depth, maximum working depth, average session duration and total hours of working).

The following lung function parameters were measured: forced vital capacity (FVC, mL), forced expiratory volume in 1 second (FEV_1, mL) and forced expiratory flow at 25–75% of FVC ($FEF_{25-75\%}$, mL/s). The FEV_1/FVC ratio (FEV_1%) was calculated. All values were adjusted to the percentage of predicted values based on the Dejsomrirutai's reference spirometric values for healthy lifetime nonsmokers in Thailand [22] except FEV_1% was not expressed as percentages.

STATISTICAL ANALYSIS

Data analysis was performed using STATA version 15.0 (StataCorp. 2017. Stata Statistical Software: Release 15.

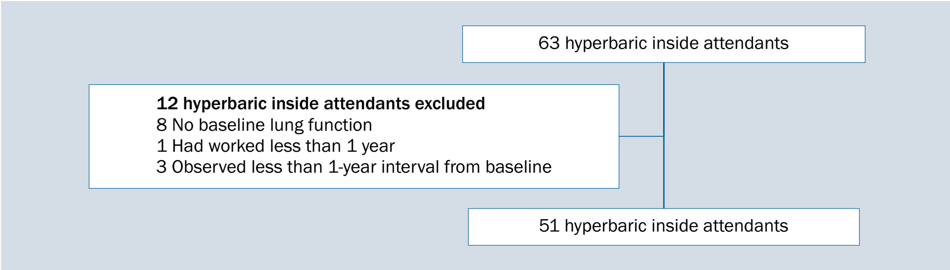

Figure 1. Flow chart of subjects inclusion and exclusion

College Station, TX: StataCorp LLC). The variables that had normal distribution were presented as mean ± standard deviation (SD) and those that did not have normal distribution were presented as median (interquartile range [IQR]). The qualitative variables were expressed in number and percentage. Mixed model was used to evaluate the change in lung function parameters over time and comparison with the change of sex-, age- and height-matched predicted values. The relationship between change on lung function parameters over time and associated factors of hyperbaric exposure were tested by mixed model (p-value < 0.25 was considered for inclusion in the model). The chosen approach was the random intercept, random slope method with an unstructured covariance matrix. The level of statistical significance was set to be 0.05.

The study was approved by the Institutional Review Board of Faculty of Medicine, Chulalongkorn University, the Research Ethics Committee of the Naval Medical Department (NMD-REC) and the Vachiraphuket Hospital Research Ethics Committee (VPHREC).

RESULTS

Fifty-one HIAs (81%) satisfied the inclusion criteria (Fig. 1). Eight subjects who had no available pre-service lung function test, 1 who worked less than 1 year and 3 subjects who had at least 2 follow-ups but less than 1-year interval from baseline were not included in the study. Forty-four (86.27%) subjects were male. At the initial pre-service examination, the mean (SD) age was 30.86 (4.78) years. The mean (SD) follow-up time was 9.26 (5.78) years. The minimum follow-up time was 1.5 year and the maximum follow-up time was 23.3 years. The mean (SD) number of follow-ups was 8.06 (3.82).

At the date of answering the questionnaire, the HIAs had a mean (SD) height of 169.39 (6.16) cm, a mean (SD) weight of 67.85 (8.67) kg and a mean (SD) body mass index of 23.63 (2.29) kg/cm^2. Thirty-three (66%) were non-smokers, 8 (16%) were previous smokers and 9 (18%) were current smokers. Only 10 (20%) had previous medical illness including hypertension, dyslipidaemia, atrial fibrillation, central nervous system lymphoma, gout, polycythaemia, dry eye, glaucoma and allergic rhinitis. None of the subjects had chronic lung diseases or history of chest or upper abdomen surgery.

There were 33 (68.75%) HIAs who had operational diving history and 45 (90%) had recreational diving experience with a median (IQR) of 13 (11.5, 2–1,000) total number of recreational dives. An average (SD) diving depth was 59.09 (25.06) feet sea water (fsw). The mean (SD) maximum depth was 93.09 (31.96) fsw.

While working in multiplace hyperbaric facilities, HIAs had an average 10.08 years of working in total (SD 6.31). The median (IQR) number of sessions was 300 (395). They accumulated a median of 500 working hours in multiplace hyperbaric chambers (IQR 570). The mean (SD) of working hours in each session was 1.70 (0.34) hours. Forty-seven (95.92%) subjects had an average working depth at 45 fsw, while only 2 (4.08%) had an average working depth at 60 fsw. There were 27 (56.25%), 12 (25%) and 7 (14.58%) HIAs who had the maximum working depth at 165, 112 and 60 fsw, respectively. The other 2 (4.16%) subjects had a maximum working depth at 45 and 120 fsw. The demographic data and working history in multiplace hyperbaric chambers are shown in Table 1.

The baseline lung function parameters of HIAs are show in Table 2. At the baseline, the mean (SD) actual FEV_1 was 3,747.45 (666.17) mL, mean (SD) actual FVC was 4,373.53 (814.67) mL, mean (SD) absolute $FEF_{25-75\%}$ was 4287.50 (1190.81) mL/s and mean (SD) $FEV_1\%$ was 86.06% (6.05). When expressed as a percentage of predicted, the mean (SD) FEV_1 was 110.38 (13.68) % of predicted, mean (SD) FVC was 108.22 (13.99) % of predicted and mean (SD) $FEF_{25-75\%}$ was 100.17 (24.29) % of predicted.

Annual changes in lung function parameters are shown in Table 3. The change of actual lung function parameters after adjusting for sex, pre-service age, height and smoking history showed that FEV_1, $FEF_{25-25\%}$ and $FEV_1\%$ significantly decreased over time, while there was no significant change in FVC. However, the comparison of actual lung function change in HIAs and the predicted values showed that there was a different change in FVC, $FEF_{25-75\%}$ and $FEV_1\%$, while there was no difference in the reduction in FEV_1 over time. The annual reduction over time in FEV_1 in the HIAs group was similar to the predicted value. The predicted value of FVC significantly decreased but in the HIAs group did not change. The decrease in $FEF_{25–75\%}$ and $FEV_1\%$ were significantly greater in HIAs compared with the predicted values. Comparison of the changes in lung function between HIAs and the predicted values is shown in Table 4. When considering the change in lung function as a percentage of the predicted values, there was no change in FEV_1, FVC and $FEF_{25–75\%}$.

There were only three hyperbaric exposures associating with lung function change over time consisting of average working depth, average session duration and total hours of working in hyperbaric chamber. The total number of working hours was also correlated with lung function change over time, but there was statistical collinearity with total hours of working, so the total hour of working was used for calculation in the model. There was a significant positive relationship between the change in actual FEV_1 and average working depth. Total hours of working were significantly positively correlated with a change in $FEV_1\%$. However, changes in actual FVC and percentage of predicted FVC were negatively correlated with total hours of working. The change in percentage of predicted FEV_1 was a significant positive relationship with average working depth and a negative relationship with average session duration. However, there was no hyperbaric exposure associated with change in actual $FEF_{25–75\%}$ and percentage of predicted $FEF_{25–75\%}$.

Table 1. Demographic data and working history in multiplace hyperbaric chambers (n = 51)

	Mean ± SD; Number (%)
Male	44 (86.27%)
Age [years]	30.86 ± 4.78
Follow-up time [years]	9.26 ± 5.78
Number of follow-ups	8.06 ± 3.82
Height [cm]	169.39 ± 6.16
Weight [kg] (n = 50)	67.85 ± 8.67
BMI [kg/cm^2] (n = 50)	23.63 ± 2.29
Smoking history (n = 50):	
Non-smoker	33 (66%)
Ex-smoker	8 (16%)
Current smoker	9 (18%)
Operation diving history (n = 48)	33 (68.75%)
Recreational diving history (n = 50):	45 (90.00%)
Total no. of dives, median (IQR) (n = 44)	13 (11.5)
Average depth [fsw] (n = 43)	59.09 ± 25.06
Maximum depth [fsw] (n = 43)	93.09 ± 31.96
Total years of working	10.08 ±6 .31
Total no. of session, median (IQR) (n = 48)	300 (395)
Average working depth (n = 49):	
45 fsw	47 (95.92%)
60 fsw	2 (4.08%)
Maximum working depth (n = 48):	
45 fsw	1 (2.08%)
60 fsw	7 (14.58%)
112 fsw	12 (25.00%)
120 fsw	1 (2.08%)
165 fsw	27 (56.25%)
Average session duration (n = 47)	1.70 ± 0.34
Total working hour, median (IQR), (n = 45)	500 (570)

BMI — body mass index; fsw — feet sea water: IQR — interquartile range; SD — standard deviation

Table 3. Annual changes in lung function in hyperbaric inside attendants

	Changes in actual values[a] Mean (95% CI)	**Changes in percentage of predicted[a] Mean (95% CI)**
FEV_1 [mL/year, %/year]	–22.52[†] (–34.07, –10.97)	+0.004 (–0.35, +0.36)
FVC [mL/year, %/year]	–8.81 (–27.12, +9.51)	+0.25 (–0.19, +0.70)
$FEF_{25–75\%}$ [mL/ /s-year, %/year]	–44.92[†] (–66.34, –23.50)	–0.36 (–0.95, +0.22)
$FEV_1\%$ [%/year]	–0.48[†] (–0.63, 0.34)	

[†]p-value < 0.05, [a]adjusting for sex, pre-service age, height and smoking history; CI — confidence interval; (–) decrease; (+) increase; FEV_1 — forced expiratory volume in 1 second; FVC — forced vital capacity; $FEF_{25–75\%}$ — forced expiratory flow at 25–75% of FVC; $FEV_1\%$ — FEV_1/FVC ratio

Table 2. Baseline lung function in hyperbaric inside attendants

	Actual values (n = 51) Mean ± SD	**Percentage of predicted (n = 51) Mean ± SD**
FEV_1	3,747.45 ± 666.17 mL	110.38 ± 13.68 %
FVC	4,373.53 ± 814.67 mL	108.22 ± 13.99 %
$FEF_{25–75\%}$ (n = 28)	4,287.50 ± 1,190.81 mL/s	100.17 ± 24.29 %
$FEV_1\%$	86.06 ± 6.05 %	

FEV_1 — forced expiratory volume in 1 second; FVC — forced vital capacity; $FEF_{25–75\%}$ — forced expiratory flow at 25–75% of FVC; $FEV_1\%$ — FEV_1/FVC ratio; SD — standard deviation

Table 4. Comparison of changes in lung function in hyperbaric inside attendants and reference values

	Changes in actual values[a] Mean (95% CI)	**Changes in reference values[a, b] Mean (95% CI)**	**P‡**
FEV_1 [mL/year]	–22.52† (–34.07, –10.97)	–20.36† (–21.77, –18.27)	0.65
FVC [mL/year]	–8.81 (–27.12, +9.51)	–14.72† (–15.96, –13.47)	0.01
$FEF_{25–75\%}$ [mL/s-year]	–44.92† (–66.34, –23.50)	–34.73† (–36.45, –33.01)	< 0.001
FEV_1% [mL/year]	–0.48† (–0.63, –0.34)	–0.21† (–0.21, –0.20)	< 0.001

†p-value < 0.05, [a]adjusting for sex, pre-service age, height and smoking history; ‡p-value of comparison between actual values and predicted values by mixed model; [b]calculated from Dejsomritrutai equation; (–) decrease; (+) increase; FEV_1 — forced expiratory volume in 1 second; FVC — forced vital capacity; $FEF_{25–75\%}$ — forced expiratory flow at 25–75% of FVC; FEV_1% — FEV_1/FVC ratio

DISCUSSION

This is a study exploring adverse long-term effects on the lung in hyperbaric chamber inside attendants. During hyperbaric oxygen therapy, hyperbaric chamber inside attendant have to stay under the same pressure as patients. However, while patients breathe 100% oxygen, HIAs breathe pressurised air for almost the entire session, an experience similar to that of scuba divers breathing from a cylinder compressed air. HIAs are exposed to the hyperbaric environment as long as they remain active in the field of HBOT, while patient treatments number in the range of 40–50 sessions. So, the discussion on results is limited to comparing with studies on hyperbaric inside attendants and commercial divers who breathe pressurised air during the course of their work.

The first point of interest relates to the value of the baseline of FVC. The percentage of predicted FVC in this study was 108.22%. Base on this data, we could infer that HIAs have larger lung than predicted. This finding is similar to other studies indicating that divers have a larger lung capacity than the normal population [7, 9–12, 16]. In addition, this result supports the idea that larger lung capacity in hyperbaric exposed workers is part of natural selection because our subjects had larger lung capacities since starting their career. Similarly, the study of Adir et al. [15] showed that there was no different in FVC between experienced and inexperienced divers with high lung capacity. In the same way, a study carried out by Skogstad et al. [12] showed there was no significant difference in vital capacity between diving students who had previous diving experiences and those who didn't. Both subgroups had more than 100% of predicted FVC at baseline.

Only one study about pulmonary function in inside attendants was a cohort study of Ozdemir et al. [6] It was a study of lung function over 1 year of 11 inside attendants compared with a matched control group of 15. They found that FEV_1%, percentage of predicted FEV_1 and $FEF_{25–75\%}$ in HIAs significantly declined in 2.3%, 3.7% and 6.9% over a year, respectively. However, there was no difference when compared with the control group. This study believed that shallow diving depth in the HIAs group is the reason why there was no difference from the control group. This contrasted with the findings in our study. We showed that there was no change in percentage of predicted for FEV_1, FVC and $FEF_{25–75\%}$ but there was a significant decrease of 0.48% per year of FEV_1%. Additionally, there were significant differences in changes of actual FVC, $FEF_{25–75\%}$ and FEV_1%, when we compared actual lung function changes in HIAs and the predicted values. A reason that changes in the percentage of predicted values for FEV_1, $FEF_{25–75\%}$ and FEV_1% were different from our study may be a fewer average number of sessions in our study. The average number of sessions in our study was 29.76 per year while the average in this study was 71.5 sessions per year. Another possible reason may be the relatively small number of inside attendants in this study resulted in higher variance in the pattern of lung function change. However, shallow diving depth might not be the main reason because average depths in both studies were similar.

In this study, there was no change in FVC over time (non-significant 8.81 mL per year reduction). Some studies supported our results that there was no change in FVC over time [12, 20]. However, a decrease in FVC among divers has been reported previously [8–10, 13, 17], with only two studies reporting FVC increase [14, 21]. Voortman et al. [21] analysed pulmonary function in 1,260 navy divers and found an increase in inspiratory vital capacity around 73 mL/year. It could be concluded that an increase in vital capacity was due to diving and training. Even if there was no increase in vital capacity in our study, there was still no decrease over time while the predicted value significantly decreased. Our hypothesis was that HIAs had adapted to hyperbaric exposure, but this effect was not strong enough to defeat natural deterioration due to the effects of aging. This is a reason why there was no change in FVC overtime but there was a difference in the change of FVC between HIAs and predicted values. In contrast with the study of Skogstad et al. [13], there was a greater reduction in FVC in divers than the control group. When expressed as a percentage of predicted, there was no significant reduction in

FVC. The result was similar to the study of Ozdemir et al. [6] as mentioned above. Almost all studies in divers found that the percentage of predicted FVC declined [9, 19] whereas Chong et al. [18] reported that percentage of predicted FVC in 116 Navy divers significantly increased over 5 years.

A change in FEV_1 in HIAs was similar to other studies in commercial divers [9, 10, 12, 13, 16, 17]. Previous studies, such as those of Tetzlaff et al. [16] and Skogstad et al. [13] that had control groups in their studies, showed the different results in comparison of FEV_1 change. A longitudinal cohort study of Skogstad et al. [13] found that there was a significant difference in change of FEV_1 over a 6 years follow-up period between 77 commercial divers and 64 non-smoking and non-diving policemen. FEV_1 in divers showed a greater reduction than the control group. This was in contrast to Tetzlaff et al. [16] and our study. In our study, there was no difference in FEV_1 reduction in HIAs from predicted value. The results were similar to Tetzlaff et al. [16] study that found decline of FEV_1 after 5 years observation in 468 male military scuba divers was no difference from decline of FEV_1 in 122 submariner. However, the pattern of change in the percentage of predicted FEV_1 couldn't be concluded in divers to be the same as with inside attendants. In our study, there was no change in percentage of predicted in FEV_1 but there was significant reduction in percentage of predicted in FEV_1 in the previous study in inside attendant [6]. The studies in divers reported either no change [9], increase [18] or decrease [9, 19] in percentage of predicted in FEV_1. Even if it was in the same study, it may show different results of reduction in FEV_1 such as a study reported by Watt [9] which observed two group of commercial divers. Although a group of 224 commercial divers that was observed for a 3–4 year period showed a reduction of actual FEV_1 but no change in percentage predicted of FEV_1, a group of 123 commercial divers that was observed for over 5 years showed both decline of actual FEV_1 and percentage predicted of FEV_1.

The HIAs also showed a loss in $FEF_{25-75\%}$ over time without any association to hyperbaric exposure factors. Normally, change in mid forced expiratory flow varied according to vital capacity so $FEF_{25-75\%}$ was not included in the criteria to be declared fit to dive. So many studies did not observe this value in their studies. However, the studies that reported $FEF_{25-75\%}$ as a parameter found a decline of $FEF_{25-75\%}$ in every study [10, 12, 13, 17, 21]. We compared change of $FEF_{25-75\%}$ in HIAs and predicted values. We found that there was a greater decrease in HIAs than the predicted values. By contrast, Skogstad et al. [13] reported that no difference in decline between divers and the control group. Focusing on percentage of predicted, there was also no change in $FEF_{25-75\%}$ as other parameters.

A reduction in FEV_1/FVC percentage (FEV_1%) was one of the concerns when deciding fitness for work in a hyperbaric environment because low FEV_1% indicated airway obstruction that may be a risk for pulmonary barotrauma during the decompression process. Our study showed a significant decrease in FEV_1% over time. Most previous studies also reported FEV_1% reduction over time in divers, even if there were different patterns of change in FEV_1 or FVC [6, 10, 18, 20, 21]. Change in FEV_1% in HIAs was more reduced than the predicted value. It may indicate that HIAs had more risk of airway obstruction than the normal population. We considered that reduction of FEV_1% was due to the higher density of breathing gas. At depth, the density of pressurized air is higher than breathing gas at surface pressure. This high gas density may increase resistance in the airways causing a decline in FEV_1%. However, there was a term of "pulmonary dysanapsis" in divers [23]. It was a disproportionate growth of FEV_1 and vital capacity. This study reported that divers who had a normal FEV_1 with a disproportionately large lung capacity had a reduction in FEV_1/FVC ratio. It seems that our study reported that the rate of reduction in FEV_1 was the same as the predicted values while FVC in HIAs did not decrease the same as the normal population. Besides declaring fitness to work in divers and HIAs, diving officers or physicians should observe the trend in changes of these lung function parameters especially FEV_1%.

In previous study, total number of dives, average diving depth and maximal diving depth were important factors associated with change in lung function parameters [6, 8, 13, 14, 17]. There were three factors in our study that correlated with lung function change consisting of average working depth, average session duration and total working hours. These were similar to the previous studies of Ozdemir et al. [6] and Skogstad et al. [13, 17] who reported that the total number of sessions or number of dives was associated with the reduction of $FEF_{25\%}$, $FEF_{75\%}$ and $FEF_{25-75\%}$. In contrast with our study, there was no association between $FEF_{25-75\%}$ and any hyperbaric exposure. We found that total working hour was associated with change of FVC, percentage predicted of FVC and FEV_1%. Similarly, previous studies in commercial divers showed that the total number of dives was related to changes in FEV_1% [20] and cumulative diving hours was related to changes in FEV_1 and FVC [14]. We also found that average working depth was associated with change in FEV_1 and percentage predicted of FEV_1. The study of Davey et al. [8] was the only study in commercial divers which reported that maximal depth was related to changes in FVC. In addition, this is the first study that showed that average session duration was correlated with percentage predicted of FEV_1.

LIMITATIONS OF THE STUDY

There are certain limitations to our study. Firstly, lung function parameters in this study are secondary data from medical records. Even with the use of standard operating procedures by certified technicians and calibration of spirometers, the quality of lung function test results may vary by medical centres. Secondly, the history of hyperbaric exposure in inside attendants was not documented each year. We collected these data at the date of answering the questionnaire. As a result, recall bias and information bias may be presented in this study.

CONCLUSIONS

In conclusion, the results indicate that working in a hyperbaric environment affects the lung function of HIAs. Additional to fitness to work implementation, periodic lung function evaluation should be encouraged to monitor further possible harm to the attendants, especially a change of FEV_1%.

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REVIEW ARTICLE

An update on stress, fatigue and wellbeing: implications for naval personnel

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ABSTRACT

The aim of the present article is to provide an update on recent research on stress, fatigue and wellbeing and discuss the implications for naval personnel. There is now considerable information on these topics in onshore civilian populations and some research on seafarers and other military personnel. This generic information can now be used to address these issues in naval personnel. In order to do this there is a need to consider specific naval contexts and to collect data to confirm the applicability of established methods and models to the navy.

(Int Marit Health 2019; 70, 2: 132–139)

Key words: stress, fatigue, wellbeing, the Navy

INTRODUCTION

After World War II the navies of many countries played a key role in fundamental research on stress and fatigue. For example, in the MRC Applied Psychology Unit at Cambridge, United Kingdom, naval ratings frequently acted as volunteers in laboratory studies of effects of noise or sleep deprivation [1]. This research was eventually extended to investigate the operational context and to attempt to find countermeasures that would maintain operational efficiency [2–4]. In onshore civilian populations there has recently been an enormous increase in research on occupational stress, fatigue and wellbeing which has not been seen to the same extent in naval personnel.

STRESS, FATIGUE AND WELLBEING IN THE NAVY

The literature on stress in the navy does cover topics other than military operational efficiency. For example, there has been research on the psychosocial and life stress characteristics of naval families [5] and on parenting stress in Navy active duty parents [6–8]. Recent research has continued to examine acute response to stress in samples of naval cadets and ratings [9–12]. Other research has evaluated methods of managing stress and shown that only educational stress briefs relevant for the target audience are beneficial [13]. There has also been interest in the use of Virtual Reality methodologies to develop Stress Inoculation Training (SIT) and Posttraumatic Stress Disorder (PTSD) treatment [14]. Other research [15] has documented the stress of military members and their families during different periods of deployment (pre-deployment; mid-deployment; and post-deployment). All phases reported suicidal ideation at very high rates (> 2%). Some studies have focused on specific operational roles (e.g. navy aviation personnel [16–18]) whereas others have investigated all members of the crew [19]. There have been many studies of occupational stress and job satisfaction in civilian populations but relatively few in the Navy (e.g. [20]). Similarly, stress and ill-health has been frequently studied in the general population but little research has been carried out with naval personnel (e.g. [21–24]).

Many of the studies of stress in naval personnel have also investigated fatigue [2, 3, 18]. Again, research has either focused on specific roles (e.g. naval aviators [25]; commanding officers [26], watch-keepers [27, 28] or a range of crew members [29]) often in operational settings [30, 31] but sometimes in non-operational settings as well [32].

Research on the Navy and wellbeing has been more recent and much of it has considered negative outcomes such as mental health problems [33–37] and suicide [38, 39].

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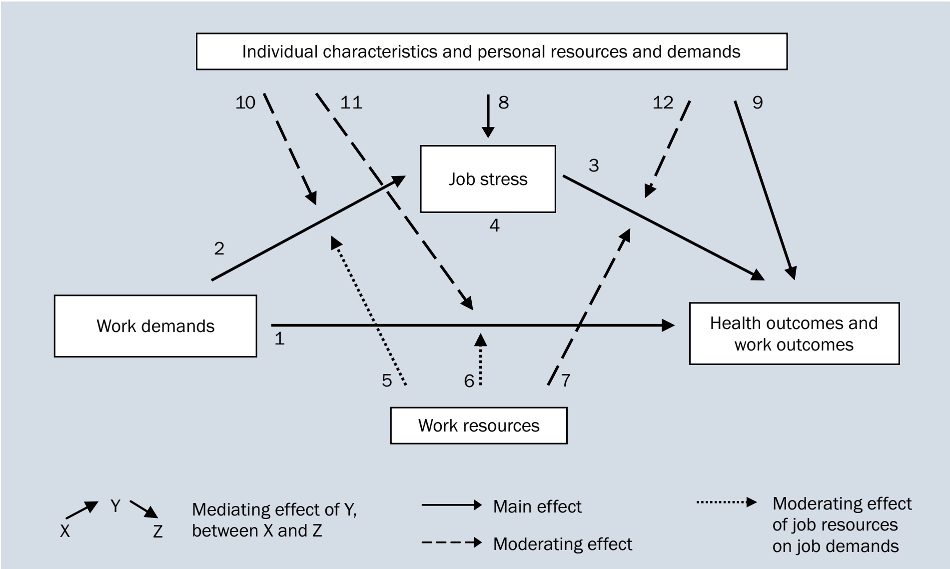

Figure 1. The Demands-Resources-Individual Effects model [48]

Comparisons have been made between specific roles (e.g. submariners) and a stratified sample of naval personnel [40]. However, other research has considered quality of life and extended this to naval nurses [41] and naval families [42]. The role of resilience and social support has also been investigated [43], as has the buffering effect of sense of belonging [44].

The next section discusses recent developments in stress, wellbeing and fatigue and considers the implication of these approaches for naval personnel.

RECENT APPROACHES TO STRESS AT WORK

The aim of this section is to review some of the research on stress and wellbeing at work that has been carried out in the last 10–15 years. The general approach adopted here is described in more detail in Smith [45, 46]. The starting point for this is a case definition of work-related stress [47] and this research considered the feasibility and possible nature of a case definition of work-related stress that is suitable for application in a variety of stakeholder domains.

A CASE DEFINITION OF OCCUPATIONAL STRESS

A case definition is needed in occupational health research as the basis for surveillance, and for monitoring the effectiveness of interventions. Cox et al. [47] examined definitions already applied in studies of work-related stress. They then identified key stakeholders and collected information on (I) the case definitions employed in their various fields and (II) their views on the feasibility of developing a single case definition that could cover all areas but remain consistent with epidemiological case definitions.

A case definition was arrived at by consensus across stakeholder groups and this case definition required the person to report:
- high levels of stress;
- unreasonable job characteristics;
- mental health problems;
- work-related problems (e.g. high sick-leave);
- the above to be work related and not due to confounding factors.

Cox et al. [47] suggested that this definition could be used for research purposes and it is supported by recent models of occupational stress. One such model, the Demands-Resources-Individual Effects (DRIVE) model [48] is described in the next section.

THE DRIVE MODEL OF STRESS

This model is shown in Figure 1. It has many of the features of earlier models of stress but puts a greater emphasis on individual characteristics and personal resources. The basic model included factors from the Demand-Control-Support (DCS) model, the Effort-Reward Imbalance (ERI) model, coping behaviours, and attributional explanatory styles as well as outcomes including anxiety, depression, and job satisfaction. These variables were categorised as work demands, work resources (e.g. control, support), individual differences (e.g. coping style, attributional style), and outcomes, although the model is intended as a framework into which any relevant variables can be applied [48]. The simple DRIVE model proposed direct effects on outcomes by each of the other variable groups, as well as a moderating effect of individual differences and resources on demands. A more complex version (the enhanced DRIVE model) was also developed to acknowledge a subjective element and included perceived stress as well as further interactive effects. Research using the DRIVE model has supported the direct effects of these variable groups on outcomes, although little support was found for interactions [49, 50]. Stronger support of direct effects compared to interactions has also been found in research on other models such as the DCS model, where reviews have shown that the buffering effect of control and support are less frequently found than the direct effects of these variables on outcomes. Research has also shown that many of the effects of job characteristics are mediated through perceived stress [51, 52].

The presence of independent effects of risk factors has led to another important methodological feature of stress research, the combined effects approach.

COMBINED EFFECTS OF OCCUPATION HAZARDS

There has been much previous research on a large number of workplace hazards, and for the most part the nature and effects of such factors have been considered in isolation. Such an approach is not likely to be representative of the real-life workplace where employees are often exposed to multiple hazards. For example, individuals are very unlikely to work in a noisy environment that does not also expose them to other stressors that have considerable potential to harm. There is limited information on the combined effects of these hazards on health and safety. Indeed, there have been no systematic literature reviews, no attempt to produce a coherent framework for studying these factors, and a dearth of studies using a variety of methods to investigate the topic.

The combined effects approach (see [53, 54]) involved summing the number of negative job characteristics (or absence of positive job characteristics) to which a person is exposed. This "Total Negative Score" was then sub-divided into quartiles and logistic regressions used to examine associations between this score and the outcomes. Table 1 shows the associations between the total negative score and high stress at work. The lowest quartile was set as the comparison group and the odds ratios show that the likelihood of being in the high stress group increases as one goes from quartile 2 to quartile 4.

The above results show a linear relationship between total negative job characteristics and perceived stress at work. Mental health outcomes and accidents at work can also be examined in this way. Other results showed that a measure of exposure to combinations of workplace factors (the Negative Occupational Factors Score) was associated with a number of health and safety outcomes, many of which were consistent across different industry sectors. Some of the associations were due to perceived stress at work whereas others were direct effects. The combined effects approach has also been shown to be important in assessing specific problems in certain occupations (see section on seafarers' fatigue). In addition, it has strong implications for the development of stress management standards. Similarly, one can use the approach to examine wellbeing at work and address the question of what is a good job (or what factors are associated with greater wellbeing and/or the absence of negative outcomes) and research on this topic is described in the next section.

Table 1. Associations between the total negative factors score (split into quartiles) and being in the high stress category (defined as reporting being very or extremely stressed at work).

	Odds ratio	Confidence interval
1st quartile	1.00	
2nd quartile	1.60	1.32–1.93
3rd quartile	2.08	1.72–2.53
4th quartile	3.84	3.17–4.66

WELLBEING AT WORK: WHAT IS A GOOD JOB?

There is a huge amount of research on negative job characteristics, occupational stress and mental health problems. However, positive and negative emotions are not just the opposite ends of a continuum, and the absence of negative emotion does not mean the presence of positive emotion. Recent approaches (e.g. [55]) have suggested that "Work is good for you." However, detailed consideration of the literature suggests that it is the absence of work that is bad for you. Indeed, work per se is not necessarily going to be good — but good work is good for you [56]. This then leads to the question of what is a good job. This could be answered in many different ways (e.g. from an economic point of view). However, within the present context the question is what psychosocial characteristics associated with work are associated with positive outcomes. A literature review [57] showed that, compared to the negative effects of work, there is very little published evidence on its positive effects. Indeed, the literature on positive aspects has many problems, such as a lack of theory, lack of data to support views and weak methodology. Measures of wellbeing are mainly outcomes and do not reflect the "wellbeing process", which is necessary to understand the topic.

Secondary analyses of large-scale surveys [58] compared the effects of the presence and absence of positive/negative job characteristics. For example, the analyses considered questions such as: "Is the presence of social support good, the absence of social support bad, or are

Table 2. Associations between the good job score (shown as quartiles) and positive mental health (a median slit into high/low groups)

	Odds ratio
Low good job	1.00
Second quartile	2.89
Third quartile	5.24
High good job	22.83

both true?" This was done by splitting the scores into tertiles (three equal parts), using the mid-value as the reference value, and examining whether equal and opposite changes occurred at opposite ends of the continuum. The results from these analyses showed that dose response did not occur for all types of association. This shows that one must examine both ends of the continuum — presence of positive features and absence of negative features — rather than inferring the effects of one from the other. Additional survey data, including positive job characteristics, appraisals and outcomes were also collected [59]. The major question addressed was what predicts positive outcomes? Again, a combined effects approach was used and the "good job score", which best predicted positive outcomes (e.g. good health; wellbeing), was the sum of the presence of positive job characteristics and appraisals and the absence of negative characteristics and appraisals. An example of this can be seen in Table 2. This shows that those with the highest good job score were nearly 23 times more likely to be in the high positive health group than those in the lowest good job category.

These pieces of research showed that there is a need for a multi-dimensional model of wellbeing at work that measures a wide range of job characteristics, job attitudes, individual characteristics and outcomes. This has been addressed by developing surveys involving short measures of a large number of concepts, and an example of this approach has been the development of the Wellbeing Process Questionnaire (WPQ) which has been used to address many of the above issues [60].

DEVELOPMENT OF THE WELLBEING PROCESS QUESTIONNAIRE (WPQ)

This relates back to the case definition of occupational stress, the DRIVE model and the measurement of wellbeing. Research on the WPQ showed that single items are often highly correlated with longer scales. This means that it is possible to have a single question measuring perceived stress, single items measuring job characteristics, and single items measuring health outcomes. In addition, possible confounding factors (e.g. personality, life outside of work) can be measured by single items. The single questions provide examples of the concept being measured and responses are made using a scale of 1–10 which allows a greater potential range of responses. An example is shown below:

- "Job Demands: I feel that I do not have the time I need to get my work done (for example I am under constant time pressure, interrupted in my work, or overwhelmed by responsibility or work demands)"
- Response: on a 10-point scale from Disagree strongly to Agree strongly

An initial study with a sample of University staff showed significant correlations between single items and full scales (average correlation for work characteristics: 0.7; average for personality: 0.66). The predictive validity was examined by testing the Job Demands-Control-Support and Effort-Reward Imbalance models with full scales and single items. Very similar results were obtained (i.e. predictive validity of single items is comparable to full scales; at risk groups based on the models can be identified with single items). This approach also allows removal of overlapping constructs. Using single items enables one to use many more concepts but these often overlap and one can determine which variables remain in the model after all have been entered into the regression. Using this technique the following constructs remained in the model: Negative job characteristics: Demands; Effort; Over-commitment. Positive job characteristics: Rewards; Control; Support; Consultation on change; Good supervisor relationship. Positive life circumstances: Uplifts; Flourishing; Social support. Negative life circumstances: Hassles. Positive Personality: Optimism; Self-esteem; Self-efficacy; Emotional stability. Negative Coping: Avoidance; Self-blame; Wishful thinking.

Using the above variables selective effects were observed. Only certain variables predicted specific outcomes. For example, work characteristics were more important for job satisfaction and job stress, whereas personality is a better predictor of positive and negative affect. A great deal of research is in progress using the approaches described here to address additional themes. First, research has investigated stress and wellbeing at work in different sectors (call centres; the police; offshore; healthcare professionals). Second, additional constructs have been examined to see how these fit into the model (ethnicity; personality; and religion). Third, different outcomes have been investigated to determine whether the approach is appropriate for them (musculo-skeletal disorders; accidents and incidents). The research has also been extended internationally to determine which effects are general and which may be culture specific. Future research will also include using the approach to evaluate interventions that change working practices and offer occupation support [61]. The general approach outlined here is that there are some ge-

Table 3. Signs and symptoms of different levels of fatigue

Likely level of fatigue	Signs/symptoms
Early warning signs of fatigue which should prompt people to look out for more conclusive evidence of fatigue	Fidgeting Rubbing the eyes
Signs of moderate fatigue suggesting performance is being affected. Take these seriously — it is not necessary to fall asleep to make a critical error	Frequent yawning Staring blankly Frequent blinking
Signs of severe fatigue. Liable to brief uncontrollable "micro-sleeps", risk of errors very high	Nodding head Difficulty keeping eyes open and focused Long blinks

neric models of stress and wellbeing that can be applied to a range of different occupations. Quite often the difficult part is knowing how a specific context translates into the more generic concepts. This will now be discussed in detail by considering seafarers' fatigue.

SEAFARERS' FATIGUE

Fatigue has been identified as a cause in major accidents such as the Herald of Free Enterprise disaster and although there is relatively little information on recognising and managing fatigue specific to the seafaring industry, there is much that can be learned from guidance devised for other sectors. For example, the Health and Safety Executive has produced various guides of its own on managing fatigue and also identifies Office of Rail Regulation guidance as being transferable to other safety critical industries. This includes Table 3 on the signs and symptoms of fatigue.

Despite an awareness that seafarers might be at particular and perhaps greater risk of fatigue than other workers because of the way that they work, until recently there has been very little research focused on them. The Cardiff Programme was one of the first studies intended to begin to fill this gap. It was designed to begin to build up a knowledge base on seafarer fatigue to:
- predict worst case scenarios for fatigue, health and injury;
- develop best practice recommendations;
- produce advice for seafarers, regulators and policy makers.

To achieve this the research included: a questionnaire survey of working and rest hours, and physical and mental health; a diary survey in which seafarers recorded their day-to-day sleep quality and work patterns; and on-board assessments of alertness and performance (such as reaction time). The questionnaire survey identified a large number of specific aspects of seafaring that were associated with fatigue. These included, for example, poor sleep quality, negative environmental factors (such as heavy seas and poor weather), high levels of job demands and stress, frequent port visits, exposure to physical hazards (such as fumes and noise) and long working hours. In particular, the survey showed that it was those who reported the greatest number of these factors that were most at risk of fatigue. In addition, seafarers who reported fatigue were more likely than seafarers who did not report fatigue to also report having poorer health, poorer well-being and reduced concentration levels, and to report having been involved in a collision. The on-board assessments showed that particular aspects of seafaring work, identified in the questionnaire and diary surveys as being risk factors for fatigue, had a detrimental impact on seafarers' levels of alertness and performance. For example, exposure to noise, working at night and a great number of days into tour were all associated with lower alertness levels and poorer performance. The diary study showed that fatigue increased most steeply during the first week of a tour. It then steadied but remained relatively higher than it was at the start of the tour. In order to consider recovery from fatigue, the survey also extended into leave. This showed that fatigue typically does not return to pre-tour levels until the second week of leave.

The Cardiff Programme showed that the potential for seafarers to experience fatigue is high because of the number of fatigue risk factors they are exposed to, many of which are unique to seafaring. More significantly, however, it made clear the importance of considering fatigue risk factors in combination — which of course, reflects the reality of seafarers' day-to-day working experience. The consequences can be felt by individual seafarers not only in the short-term (in terms of fatigue symptoms including, for example, confusion, tension and loss of concentration), but also in the longer-term (being associated with the development of poorer physical and mental health and reduced well-being). They also impact on vessels, crews, cargos and the environment (for example as a result of collisions).

Smith et al. [62] describe risk factors for ship collisions and groundings. These included:
- fatigue;
- alcohol/substances;
- illness;

- uncertainty about responsibilities;
- communication problems;
- poor communication between ships and/or authorities;
- distraction;
- poor bridge design;
- inadequate means of navigation;
- inadequate use of navigational aids;
- overload;
- alarms suppressed/ignored/misinterpreted;
- lack of personnel;
- external pressures;
- poor weather conditions.

Two important conclusions can be drawn from the list above. First, accidents are caused by multiple inter-related factors. For example, a lack of personnel may lead to an accident when weather conditions have been poor, as the crew have become fatigued. Fatigue in turn will lead to an increased likelihood of distraction, poor communication and overload. Secondly, in terms of reducing the likelihood of accidents, it's important to distinguish between causal and symptomatic factors. Whilst fatigue is a cause of accidents, it sits in a chain of events and is rarely the initial, triggering factor. By contrast, core systemic factors such as manning need to be the focus of intervention.

THE WAY FORWARD

A main recommendation from the Cardiff fatigue research was that seafarers' fatigue should be treated as a health and safety issue. Demonstrating that fatigue is a multi-factorial process with wide ranging significant consequences also makes it clear that addressing fatigue requires a multi-level approach. Making specific, isolated recommendations to one level of the industry will have limited effect unless the bigger picture is considered. For example, it might be suggested to crew members that they ask for assistance if they feel fatigued. A broader perspective would recognise that this may not be possible if the ship is under-manned. The reason the ship is under-manned may be because of market conditions and competition with other companies who operate with fewer crew. The reason for ships having fewer crew may be because of competition between flag states for registration, which has allowed manning levels to decrease. Recommendations which ignore these wider factors will be of little value to the industry. At the highest level, international legislation is essential in combating excessive working hours. The evidence suggests that existing efforts to date have been inadequate. Establishing standards both for measuring fatigue and for recording and auditing actual working hours would undoubtedly accelerate progress. As the research has shown, fatigue is much more than working hours, but knowing how long seafarers are working is critical in terms of evaluating how safe operating standards are, and current working hours recording systems have been shown to be inadequate.

TO FINISH WITH A POSITIVE MESSAGE

Recent research on stress, fatigue and wellbeing has some clear implications for naval personnel. Audit tools are now available and can be used to assess these factors over time. Longitudinal studies are important because they provide a clearer indication of causal links and such studies have been carried out successfully using the measuring instruments described in this paper. These measuring instruments should include surveys, diaries and objective measurement of cognitive performance and physiology. Indeed, the development of microbiological techniques suggests that a simple objective stress test may be getting closer. Objective cognitive testing can now also be carried out in remote locations and this can be supported by other forms of mobile recording.

Developments in education and training will also help those who are working away from home. Use of appropriate working away strategies can improve quality of life and subsequent wellbeing [63]. This can now be developed into an educational programme that enables better coping with being away from home. Stress or fatigue training has also now become more sophisticated and one successful approach [64] has the following format:

1. Education — providing appropriate information about stress or fatigue;
2. Personal relevance — getting the person to consider their own stress and fatigue;
3. Nudges to prevent or reduce these problems — consider small manageable changes rather than trying to completely change the job;
4. Personal commitment — this is a crucial part of training which will lead to use of the approach at a later date.

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LETTER TO THE EDITOR

"Champimer" project: investigation of fungal diversity at the air-water interface of maritime environment

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The marine environment is known for its biological and microbiological diversity. A recent review of the literature has described the diversity of pathogen microorganisms in seawater [1]. Moreover, it is well-known that the air contains several pathogenic microorganisms. But few studies investigate it. Marks et al. [2] found between 0 and 1200 CFU fungus per cubic meter of air within the maritime environment, depending on the location and the seasons; however, no fungus identification was given. The aim of the "Champimer" project is to investigate the fungus diversity at the air-water interface of maritime environment. This project is part of a partnership between the French Society of Maritime Medicine, the Resource Centre for Occupational and Environmental Pathologies of the University Hospital of Brest, the Medical Analysis Laboratory of the Military Hospital of Brest, and the Host-Pathogen Interaction Study Group of the University of Brittany–Loire.

Our study comprises four air sampling campaigns, one of each season, on Brest Harbour, Brest roadstead and on the Iroise Sea, in order to draw up a mycological cartography applied to military sailors, fishermen, as well as leisure sailors (Fig. 1). The air samples were taken from the open air, on the wheelhouse's roof of a ship belonging to the university. This ship is a trawler adapted for scientific research. Air was impacted in 15 mL of liquid medium using the Coriolis µ® air sampler (10 min, 300 L/min). After centrifugation, the pellet was divided for fungus isolation on agar media malt agar (incubated at 27°C), DG18 (incubated at 27°C) and DG18 (incubated at 37°C). The identification of fungi was based on macroscopic and microscopic examination, and by analysing 28S and ITS loci when fungi were not microscopically identified.

We have already realised and analysed air samples collected during the winter. No cultivable fungi were detected in samples taken in the Iroise Sea, whereas samples taken on Brest Harbour and Brest roadstead showed *Cladosporium sp.*, *Eutypa lata* or *Aspergillus* section *fumigati*.

Aspergillus and *Cladosporium* may induce asthma manifestations or keratitis [3–5]. *Cladosporium cladosporioides* was also described to cause dermatological disease [6]. We aim to explore the fungal diversity over the four seasons on Brest Harbour, Brest roadstead and on the Iroise Sea and to collect epidemiological and clinical data on sea users.

These first results showed some fungi at the air-sea-water interface in winter. The origin of these fungi may be telluric. This project will be proceeded over a year, three seasons more.

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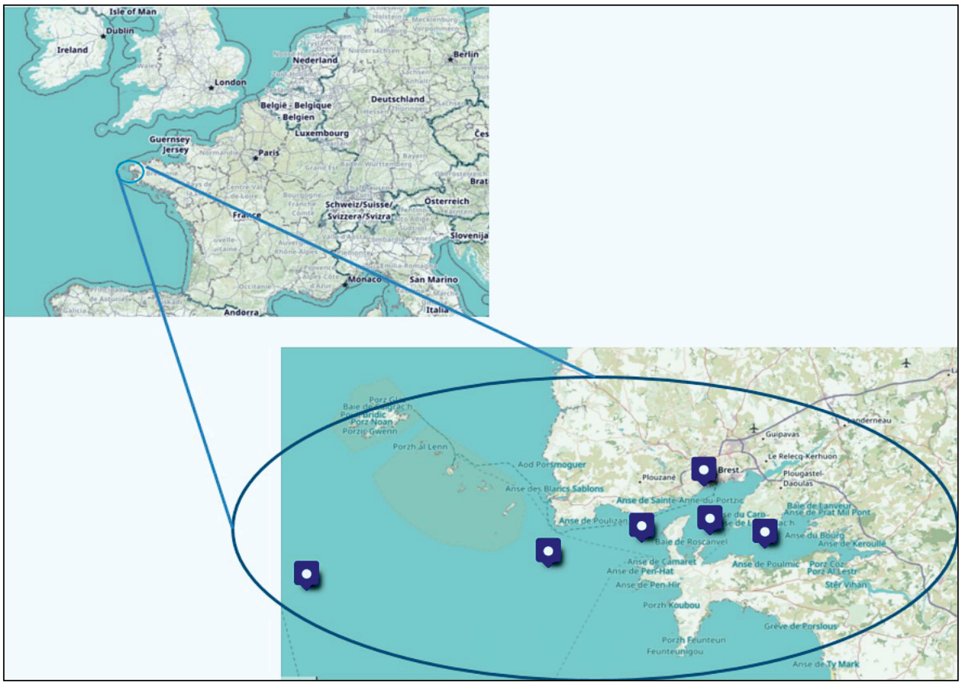

Figure 1. Spots of the air-water interface samples

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4TH INTERNATIONAL CONGRESS OF MARITIME, TROPICAL, HYPERBARIC AND TRAVEL MEDICINE

"Health safety onboard and during journey"

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Venue: Conference Centre of Pomeranian Science and Technology Park, Gdynia

26th–28th of September 2019

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The International Maritime Health will publish original papers on medical and health problems of seafarers, fishermen, divers, dockers, shipyard workers and other maritime workers, as well as papers on tropical medicine, travel medicine, epidemiology, and other related topics.

Typical length of such a paper would be 2000–4000 words, not including tables, figures and references. Its construction should follow the usual pattern: abstract (structured abstract of no more than 300 words); key words; introduction; participants; materials; methods; results; discussion; and conclusions/key messages.

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All articles should be submitted to IMH electronically online at www.intmarhealth.pl where detailed instruction regarding submission process will be provided.

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