

Effects of noise exposure among navy personnel

Hearing loss and cognitive performance

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Scientific environment

The project “Noise and health in the Navy” was carried out by the Research Group for Occupational and Environmental Medicine, Department of Global Public Health and Primary Care, Faculty of Medicine and Dentistry at the University of Bergen, Norway in cooperation with the Occupational Health Service and the Medical Services of the Royal Norwegian Navy (RNoN).

Contributions to the project have also been made by collaborators from the following scientific units:

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- Norwegian Centre for Maritime Medicine, Haukeland University Hospital, Bergen, Norway

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Abbreviations

ANOVA	Analysis of Variance
CI	Confidence Interval
dB(A)	A-weighted decibel scale
dB(C)	C-weighted decibel scale
GLM	General Linear Model
HCP	Hearing Conservation Programme
HSE Navy	Health, Safety and Environment in the Navy
HUNT	The Nord-Trøndelag Health Study
Hz	Hertz
ISO	The International Organization for Standardization
LAeq	Equivalent noise level
MRI	Magnetic Resonance Imaging
ms	Milliseconds
NHN	The project “Noise and Health in the Navy”
NIHL	Noise-Induced Hearing Loss
NLIA	The Norwegian Labour Inspection Authority
NRAR	The Royal Norwegian Navy Standard Requirements and Regulations

OSHA	US Occupational Safety and Health Administration
Pa	Pascal
PTS	Permanent Threshold Shift
RNoN	The Royal Norwegian Navy
RR	Relative Risk
RT	Response Time
SEM	Standard Error of the Mean
STS	Significant Threshold Shift
TTS	Temporary Threshold Shift
WHO	World Health Organization

Abstract

Background

Due to concerns regarding safety and health in the work environment of the Royal Norwegian Navy (RNoN), a questionnaire-based survey was conducted (2002 – 2003) to assess work-related risk factors and health problems among Navy personnel. Results from this questionnaire study showed noise exposure as an important risk factor, and impaired hearing as an important health problem among Navy personnel. Also foreign navy studies point at noise exposure as a prevalent risk factor and hearing loss as a common health complaint among navy personnel. However, the literature concerning noise exposure and hearing loss in the navy is sparse and the issue has not been systematically investigated.

The RNoN has experienced several accidents at sea. These accidents have been found to be associated with cognitive requirements regarding navigational task performance. Prior literature has indicated deleterious effects of noise exposure on cognitive performance. Thus, an association between RNoN navigation accidents and impaired cognitive performance due to noise exposure has been questioned. However, research on noise exposure and cognitive performance in naval and maritime settings is limited and shows contradicting results.

Objectives

The main objective of this thesis was to gain more knowledge regarding the effects of noise exposure among navy personnel. The specific objectives of paper I were to assess the prevalence of hearing loss among Navy personnel and to examine the association between work on board vessels in the RNoN and hearing loss among Navy personnel. In paper II we aimed at investigating the incidence of significant threshold shift (STS) among Navy personnel between 2012 and 2014 and to identify determinants of STS among Navy personnel. The objective of paper III was to assess cognitive performance subsequent to noise exposure among Navy personnel on board RNoN vessels.

Material and methods

938 officers, enlisted and civilian Navy personnel from 48 vessels were invited to participate in a study on the relationship between noise and hearing loss. The study was conducted between 2012 and 2014 and comprised two examinations per person, i.e. at baseline and follow-up. Two separate questionnaires on noise exposure and health were prepared, one for each examination. Hearing was assessed by pure tone audiometry. At baseline, hearing loss was defined as hearing thresholds ≥ 25 dB in either ear at 3000, 4000 or 6000 Hz. At follow up, impaired hearing was defined as a STS, i.e. an average change in hearing thresholds between the two examinations $\geq + 10$ dB at 2000, 3000 and 4000 Hz in either ear.

Two to five Navy personnel on board 24 RNoN vessels were selected to participate in a study on the effects of noise exposure on cognitive performance. Noise exposure was assessed by personal noise dosimeter measurements, while cognitive performance was evaluated by using a visual attention test in which response time (RT) was measured. In order to assess possible confounding factors, the participants completed a log book.

Results

The prevalence of hearing loss among Navy personnel at baseline was 31.4 %. Work on board RNoN vessels was significantly associated with reduced hearing after adjusting for age, gender and otitis as an adult. The incidence of STS from baseline to follow-up was 23.0 %. The noise exposure determinants ‘current exposure to loud noise > 15 hours/week during work on board’ and ‘number of gun shots during the last year’ were significantly associated with a higher risk of STS.

A significantly increased RT was found among participants with the highest noise exposure (>85.2 dB(A)) and the next highest noise exposure (77.1 – 85.2 dB(A)) compared to participants with the lowest exposure (< 72.6 dB(A)).

Conclusions

The prevalence of hearing loss and incidence of STS among Navy personnel was 31.4 % and 23.0 %, respectively. In the cross-sectional study, an association between work on board RNoN vessels and hearing loss was found. In the longitudinal study, we found a

significant association between STS and current exposure to loud noise > 15 hours/week on board RNoN vessels. We also found a significant association between STS and number of gun shots during the last year. The Navy personnel with the highest noise exposure performed poorer on a cognitive performance test than personnel with the lowest noise exposure.

It is likely that noise exposure on RNoN vessels causes hearing loss and affects cognitive performance among the Navy personnel on board.

List of publications

This thesis is based on the following papers:

Irgens-Hansen, K., Sunde E., Bråtveit M., Baste V., Oftedal G., Koefoed V.F., Lind O., Moen B.E. (2015): “Hearing loss in the Royal Norwegian Navy: a cross-sectional study”, *International Archives of Occupational and Environmental Health*, 88(5), 641 – 649.

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PAPER I – III

Appendix I: Maximum allowed noise levels in accordance with the Royal Norwegian Navy Standard Requirements and Regulations (NRAR)

Appendix II: Project information to the Navy personnel (in Norwegian)

Appendix III: Baseline questionnaire (in Norwegian)

Appendix IV: Follow-up questionnaire (in Norwegian)

Appendix V: Procedure concerning referrals (in Norwegian)

Appendix VI: Test procedure for hearing examination (in Norwegian)

Appendix VII: Log book (in Norwegian)

1. Introduction

1.1 Background

Since the 18th century, the causal association between noise exposure and hearing loss has been recognized.¹ Noise exposure is a well-known health risk in the military, mentioned since the 19th century in a number of reports on hearing loss.² Consequences in terms of need of hearing protection in military personnel have been inherent, but not necessarily always enforced.³ In the 1950s, the US Armed Forces established a hearing conservation programme (HCP),³ evaluated in a number of publications.⁴⁻⁶ Also in the Norwegian Armed Forces, attention has been paid to the issue, i.a. through a publication concerning noise and hearing on board motor torpedo boats and submarines in 1957⁷ and in terms of a prophylactic programme suggested in the 1980s.⁸ However, even though instructions how to protect the personnel from noise exposure have been issued,⁹ the effects from these types of interventions remains to be elucidated.

Between 2002 and 2003, the University of Bergen conducted a questionnaire-based study on working conditions and health among personnel in the Royal Norwegian Navy (RNoN), titled “Health, Safety and Environment in the Navy” (HSE Navy).^{10,11} The study was established as a result of several media headlines questioning the safety of the work environment in the RNoN.¹¹ The purpose was to study possible risk factors regarding work in the RNoN and to assess whether these risk factors could be related to past and present health

problems among the Navy personnel. Several potential risk factors were identified and one of the most prominent was noise. Among the 2265 responders, 840 (38 %) answered that they were exposed to “much” or “very much” noise during work in the RNoN. In addition, self-reported hearing loss was found among 531 (24 %) of the workers.¹⁰

These results were different from those of an interview-based survey among general employees in the Norwegian work force, in which 8 % answered that they were exposed to high noise levels at work while 3 % reported hearing loss.¹² Thus, based on the findings from the HSE Navy questionnaire study it was concluded that self-reported prevalence of noise exposure and hearing loss was much higher in the RNoN than in the general Norwegian population, and that a causal relationship between noise exposure in the RNoN and development of hearing loss was likely.^{10,13}

These findings, combined with already existing reports presenting high noise levels in many RNoN vessels,⁹ represented the background of the project “Noise and Health in the Navy” (NHN) which was commenced in 2012. The project aimed at assessing noise levels on board all RNoN vessels and potential effects of noise exposure, in order to improve working conditions on board RNoN vessels and thus fulfilling the “regulation concerning work environment, safety and health among seafarers”.¹⁴ The present thesis is based on results from the NHN project and is focusing on associations between noise

exposure on board RNoN vessels and hearing loss as well as cognitive performance (Figure 1).

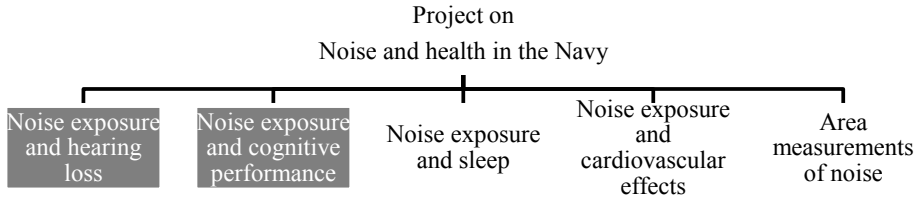


Figure 1. Project on Noise and Health in the Navy. Grey boxes include the effects of noise exposure on Navy personnel being presented in detail in this thesis

1.2 The Royal Norwegian Navy (RNoN)

With the second longest coast line in the world¹⁵ and vast ocean areas almost seven times larger than the Norwegian mainland;¹⁶ RNoN has a large area to control and protect. The RNoN also provides operational deployment in international crises and peacekeeping operations, for instance by protecting ships from piracy in the Gulf of Aden and transporting chemical weapons from Syria for safe destruction.

1.2.1 The Navy bases

The RNoN's main Navy base Haakonsværn is situated outside the city of Bergen. In addition, there is a Navy base with a more limited capacity situated in the municipality of Ramsund in the Northern part of Norway. The RNoN's Coast Guard base is located in the city of Sortland, also in the Northern part of Norway.

1.2.2 The RNoN vessels

The RNoN comprises the Fleet and the Coast Guard.¹⁷ The major task of the Fleet is to make maritime resources available in peacetime, crisis and war¹⁸ while the most important tasks of the Coast Guard include fisheries and environmental protection, search and rescue and custom control.¹⁹ The Fleet consists mainly of four different vessel classes: the frigates (Fridtjof Nansen class), the corvettes (the Skjold class), the mine vessels (Oksøy and Alta class) and the submarines (Ula class) (Figure 2). The Coast Guard consists of 15 vessels of various sizes with different characteristics (Figure 3).¹⁷



Figure 2. Vessel classes in the Fleet. a) Fridtjof Nansen class b) Skjold class
c) Alta and Oksøy class d) Ula class. Photos: the Norwegian Armed Forces Media Archive



Figure 3. Selection of vessels in the Coast Guard. a) KV Harstad b) KV Magnus Lagabøte
c) KV Svalbard d) KV Tor Photos: the Norwegian Armed Forces Media Archive

1.2.3 The Navy personnel

To ensure that the personnel on board are without sickness or injury and making them fit for service without imperilling the safety and health of others, Navy personnel are selected for work on board according to medical criteria defined by specific regulations.^{20,21} In 2014, the number of man-labour years in the Fleet was 3231, while the equivalent number in the Coast Guard was 819.²²

1.3 Noise exposure

1.3.1 Noise

Noise is the subjective equivalent to the physical phenomenon: *sound*. Noise is per definition *unwanted sound*.²³

Physically sound can be described as a series of small pressure variations around an equilibrium. The magnitude of these variations is described by the *sound pressure*, and the variation rate is described by the *sound frequency*.²⁴

The word *sound* is also used for the sensory perception of these pressure variations.

The sound pressure is expressed in pascal (Pa). The pressure may be given in absolute unites; pascal= Newton/m². However, it is customary to use a logarithmic scale, and express the sound pressure in decibels (dB) in relation to a reference pressure. The standard reference pressure for sound in air is 20 μPa.²⁴

$$\text{Sound pressure level in decibels} = 10 * \log\left[\frac{p^2}{p_{ref}^2}\right] = 20 * \log\left[\frac{p}{p_{ref}}\right]$$

The softest or weakest sound pressure level a normal human ear can detect is about 0 dB. At sound pressure levels above approximately 130 dB the sensory sensation is more associated with pain than sound.²³

The sound frequency is the number of pressure variations per second, and is expressed in Hertz (Hz). Pitch is the subjective equivalent to the physical phenomenon *frequency*. Higher frequencies are associated with a higher pitch. The normal human ear can detect frequencies roughly in the range 20 to 20 000 Hz.²⁴

The human ear is not equally sensitive to sounds at different frequencies. The highest sensitivity is around 2000 – 4000 kHz, and the sensitivity is decreasing towards higher and lower frequencies. To account for this unlinearity, weighting networks have been developed. The most common weighting networks are designed to approximate the equal-loudness curves at low (dB(A)) and high sound pressure levels (dB(C)).²⁵

1.3.2 Perception of sound

Sound waves (a series of pressure variations) entering the ear canal reach the ear drum which starts to move.²⁶ The energy from the sound wave is then transferred through the bones of the middle ear (ossicles) to the oval window of the fluid-filled cochlea. The basilar membrane that runs along the cochlea is set in motion with maximum amplitude close to the oval window for high frequencies and closer to the apex for low frequencies. The organ of Corti which is connected to the basilar membrane contains sensory cells with stereocilia, hair cells. When the basilar membrane moves, the "hairs" are deflected, resulting in synaptic transfer of an impulse to the auditory nerve and further to the central nervous system.

Depending on the complex pattern of the sound waves, the sound may be labelled *noise*, *music*, *speech*, *etc.* The noise, i.e. the unwanted part of the sound, can be perceived as continuous or intermittent. The sound pressure may be steady with small variations or the opposite. The character may be impulsive ("bangs" and "clicks"), it may be

tonal with audible tones, it may be high-pitched (have many high frequency components) or low-pitched (with lots of bass components). The annoying properties of the sound depends on the character, but the total amount of perceived sound energy regardless of character, described by the equivalent A-weighted sound level, is the most important parameter regarding hearing damage.²⁷

1.3.3 Effects of noise exposure

Noise exposure is associated with both auditory and non-auditory effects. Impaired hearing is the most documented of the auditory effects. Impaired hearing due to noise exposure may occur as a result of mechanical (e.g. tympanic rupture) or neurogenic damage (damage of the stereocilia of the hair cells or biochemical overload and rupture of synapses to the auditory nerve.²⁶ Regeneration may restore function, but if level and duration of noise has been too high, hair cells will die, resulting in a permanent hearing loss. Hearing loss due to chronic noise exposure usually begins at 3000 – 4000 Hz. Recently, a reduced amplitude of wave I in the auditory brain-stem response has been found to correlate to noise exposure in otherwise normal-hearing subjects.²⁸ This is probably due to loss of synapses and indicates that some damage to hearing occurs before audiometric changes are apparent.

A temporary threshold shift (TTS) is a response to loud noise exposure. The shift is temporary as recovery ensues after a certain period of rest under low noise conditions.²⁹ Excessive exposure to high noise levels may also cause a permanent threshold shift (PTS).

The connection between TTS and PTS, however has not yet been established.

The non-auditory effects of noise exposure include effects on cognitive performance, communication difficulties, sleep disturbance, cardiovascular effects and annoyance.^{23,30} The mechanisms of non-auditory effects are however less documented. However, the societal cost of such effects has been well established.³¹

1.3.4 Noise exposure regulations and recommendations

In Norway, separate noise exposure regulations have been issued for work at shore and for work at sea. These regulations are made to protect hearing and to secure adequate concentration and communication. In the land-based regulation the 8 hour limit value for noise exposure is 85 dB(A), while the maximum peak level is 130 dB(C).³² The regulation at sea is less strict with a 8 hour limit value of 87 dB(A) and a peak level of 140 dB(C).¹⁴ The land-based regulation provides specific limit values for certain work with respect to concentration and communication. Similar considerations are made in the regulations at sea, as specific limits for different locations on board (e.g. bridge, cabins and engine rooms). The RNoN is excepted from the paragraph which concerns noise exposure limits in different locations.¹⁴ Instead, the RNoN has developed a separate document: the “Royal Norwegian Navy Standard Requirements and Regulations” (NRAR) to attain vessels with controlled environmental standards (Appendix I). The NRAR defines maximum allowed noise levels related to hearing damage and speech intelligibility for safety

reasons.³³ The noise levels presented in the NRAR are mostly concurrent with the Norwegian regulation at sea¹⁴ and the guidelines for the acoustical environment in NATO surface ships.³⁴

Several guidelines give recommendations on noise exposure limits.^{27,35,36} One of the most commonly available guidelines (ISO 1999:2013) has been issued by the International Organization for Standardization (ISO); an independent, non-governmental organization which prepares different international standards through technical committees.³⁷

The ISO 1999:2013 standard on estimation of noise-induced hearing loss is based on experimental data in which the daily noise exposure did not exceed 12 hours.²⁷ Thus, the assumptions made in this standard do not necessarily apply to Navy personnel being continuously exposed to noise for days or weeks. The knowledge regarding the auditory and non-auditory effects of long term and uninterrupted exposure to noise is scarce. The World Health Organization's (WHO) guidelines for community noise and the American conference of Governmental Industrial Hygienists Publication both recommend noise levels of 70 dB(A) or below in order to avoid hearing impairment when exposed to noise for more than 24 hours.^{23,38} The WHO guidelines do also include recommendations regarding noise exposure and communication, sleep, cardiovascular effects and annoyance.²³ Complete speech intelligibility is found achievable with a raised voice for noise levels up to 55 dB(A) and with straining vocal effort for noise levels of 65

dB(A). In order to avoid sleep disturbance, noise levels should not exceed 30 dB(A) for continuous noise and 45 dB(A) for noise events. To avoid cardiovascular effects, the guidelines suggest that noise levels should not exceed 65 – 70 dB (LAeq,24h). The guideline noise levels for annoyance are 50 – 55 dB at daytime and 5 – 10 dB lower during the evening and at night.

The noise levels recommended by the WHO guidelines for community noise are frequently exceeded on board RNoN vessels.³⁹

1.3.5 Noise exposure on board navy vessels

Navy personnel are exposed to noise on board navy vessels, often for long periods (days or weeks). Continuous noise is a major contributor, and is mainly generated by the vessel's propulsion (e.g. engines, propellers, thrusters etc.). The personnel are furthermore exposed to impulse noise from firearms. Few previous studies have been published on maritime noise levels.

The navy studies available have all reported on noise levels exceeding current standards.⁴⁰⁻⁴² A maximum noise level of 68.8 dB(A) was measured in the cabins on board a Korean Navy vessel.⁴² At the flight deck on board US aircraft carriers, noise exposure was found to exceed 150 dB(A).⁴¹ In a UK study, noise exposure when firing a heavy machine gun peaked at 122.7 dB(C) on the bridge of a navy vessel.⁴⁰

High noise levels have also been reported in commercial vessels. On board fishing vessels and tankers, noise levels in the engine rooms

reached around 95 to 110 dB(A)⁴³⁻⁴⁵ while the noise levels in engine control rooms on board Norwegian ferries ranged between 70 and 90 dB(A).⁴⁶

As part of the NHN project, noise measurements were performed on board 40 of the RNoN's vessels by the Research group for Occupational and Environmental Medicine at the University of Bergen.

Area measurements were performed in different operating modes and in locations in which the Navy personnel were likely to spend time. Detailed results from this investigation have been presented in reports to the RNoN.⁴⁷ Results from 14 of the 40 RNoN vessels (representing frigates, corvettes, mine vessels and Coast Guard vessels) have recently been published by Sunde et al.³⁹

The highest noise levels were found in the corvettes with median noise levels ranging from 71.7 to 95.0 dB(A), while the lowest noise levels were found in the Coast Guard vessels with median noise levels ranging from 41.5 to 57.8 dB(A)). For all vessel classes, the highest noise levels were found in the engine rooms, with median noise levels ranging from 86.4 dB(A) (frigates) to 105.3 dB(A) (mine vessels and corvettes). The median noise levels on the bridge varied between 47.9 dB(A) (Coast Guard vessels) and 74.1 dB(A) (corvettes). The median noise levels in cabins varied from 41.5 dB(A) on board the Coast Guard vessels to 77.7 dB(A) on board the corvettes.



Figure 4. Examples of locations in which noise exposure was measured. a) the bridge on board a Coast Guard vessel b) the engine room on board a corvette. Photos: The Norwegian Armed Forces Media Archive

1.4 Effects of noise exposure on navy personnel

1.4.1 Hearing loss

Noise-induced hearing loss (NIHL) is world-wide regarded as one of the most prevalent work-related diseases and represents between 7 and 21 % of all cases of disabling hearing loss in adults.⁴⁸ In a large population based study in Norway, disabling hearing loss (defined as a pure-tone average for the better ear for frequencies of 500, 1000, 2000 and 4000 \geq 35 dB) was found among 10.3 %.⁴⁹ Hearing loss is frequently found in highly noise exposed work places, such as the construction industry, the mining industry and the military.^{50 51}

No common definition exists on hearing loss. Definitions vary to a great extent by the selection of frequencies, hearing thresholds, ears (worst, best or both) and number of available hearing tests, thus making it difficult to compare studies. When considering the effects of noise exposure on hearing, the frequencies 3000, 4000 and 6000 Hz are commonly selected. In order to assess comprehension of speech,

one would predominantly assess hearing at the frequencies 500 – 4000 Hz. In several previous military studies, hearing loss has been defined by a shift in hearing threshold between two audiometries. This shift is commonly denoted either as a significant threshold shift (STS) or a permanent threshold shift (PTS).

In a PubMed search, nine studies concerning hearing loss in the navy were found (Table 1). The available literature is primarily based on studies conducted in the US Navy between 1995 and 2007.^{4-6,52-54} However, some recent studies have been conducted in in the Australian Defence Force⁵⁵ and the Royal Thai Navy.⁵⁶ The occurrence of hearing loss has been found to range between 11.0 and 29.0 %.^{4-6,53-56} In the US Navy, a significant association between noise exposure on board navy vessels and hearing loss has been found.⁵⁴ US Navy studies have further indicated a higher risk of hearing loss in certain job specialities on board navy vessels.^{4,5,53} This was also suggested in one of the first published studies (1957) emphasising hearing loss among Navy personnel. In this study it was demonstrated that hearing loss was less frequent among deck hands (17.0 %) than among engine crews (24.8 %) working on board Norwegian motor torpedo boats and submarines.⁷

Table 1. Overview of studies on hearing loss among navy personnel

Country (published)	Study design (study period)	Study population (n)	Definition and (occurrence of hearing loss)	Additional results
Norway ⁷ (1957)	Cross sectional (not stated)	Motor torpedo boat and submarine ratings (358)	Acousto-traumatic hearing reduction (no definition given) (20.4 %)	Acousto-traumatic hearing reduction more common among engine crew (24.8 %) than among deck hands (17.0 %)
US ⁴ (1995)	Longitudinal (1987 – 1990)	Naval fleet personnel (12 492)	STS: average change in HT at 2, 3 or 4 kHz \geq 10 dB or \geq 15 dB change at either of the frequencies 1,2,3 or 4 kHz (29.0 %)	STS varied by job speciality (5.0 to 70.2 %)
US ⁵ (2002)	Longitudinal (1995 – 1999)	Navy enlisted personnel (54 057)	STS: average change in HT at 2, 3 or 4 kHz \geq 10 dB or \geq 15 dB change at either of the frequencies 1,2,3 or 4 kHz (18.1 %)	STS varied by job speciality (5.4 to 25.0 %), however the authors claimed no intuitive correlation between the noise exposed groups and STS
US ⁵² (2002)	Cross sectional (1995 – 1999)	Navy enlisted personnel (68 632)	Mean HT	Mean HT were worse than expected by OSHA
US ⁶ (2004)	Longitudinal (1995 – 1999)	Navy officers and enlisted personnel (83 694)	STS: average change in HT at 2, 3 or 4 kHz \geq 10 dB or \geq 15 dB change at either of the frequencies 1,2,3 or 4 kHz (Officers 13.3 % Enlisted 17.9 %)	STS was significantly lower for officers than enlisted
US ⁵³ (2004)	Longitudinal (not stated)	Navy flight deck personnel, engineers and administrative personnel (205)	PTS: average deterioration in HT at 2,3 or 4 kHz \geq 10 dB or \geq 15 dB deterioration at either of the frequencies 1,2,3 or 4 kHz (Flight deck personnel 26 % Engineers 21 % Administrative personnel 15 %)	An increased risk of hearing impairment found among flight deck personnel and engineers compared to administrative personnel
US ⁵⁴ (2007)	Longitudinal (1982 – 2004)	Navy enlisted personnel (267 658)	STS: average change in HT at 2, 3 or 4 kHz \geq 10 dB or \geq 15 dB change at either of the frequencies 2,3 or 4 kHz (11.0 %)	Duty on board surface warships more damaging to hearing than duty at shore
Australia ⁵⁵ (2012)	Cross sectional (not stated)	Navy personnel (693)	HL: average HT > 25 dB at 3000, 4000, 6000 and 8000 Hz (15.1 %)	A significant difference in prevalence of hearing loss between the Army (21.3 %), Navy (15.1 %) and the Air Force (9.9 %)
Thailand ⁵⁶ (2014)	Cross sectional (2009)	Naval officers (149)	HL: HT \leq 25 dB at 0.5, 1 and 2 kHz and greater abnormal hearing (> 35 dB) in the same ear at 4 kHz than at 8 kHz (22.8 %)	-

STS: Significant threshold shift

HT: Hearing threshold

OSHA: Occupational Safety and Health Administration

PTS: Permanent threshold shift

HL: Hearing loss

1.4.2 Cognitive performance

Cognition is defined as “the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses”.⁵⁷ Thus, cognitive performance can be explained as the capability to acquire and utilize this knowledge and understanding. Different tests have been used in prior research to assess cognitive performance, such as tests on working memory and attention.⁵⁸

In order to secure safe navigation and accurate warfare abilities on board RNoN vessels, Navy personnel rely on quick and correct reactions without being distracted. The RNoN has experienced a number of accidents at sea throughout the years and previous research has indicated an association between these accidents and cognitive requirements regarding navigational task performance.⁵⁹

Previous research also suggests that noise may increase the risk of occupational accidents⁶⁰⁻⁶³ and have harmful effects on cognitive performance.⁶⁴ The degree of harmful effects have been shown to depend on factors such as noise duration, intensity and the complexity of the task performed.⁶⁴ Few previous studies have evaluated cognitive performance subsequent to noise exposure⁶⁵⁻⁶⁸ and research concerning the effects of noise exposure on cognitive performance at sea is sparse. The reduced cognitive performance described among navy personnel and seafarers in previous studies have been explained by low-frequency noise and intermittent noise.⁶⁹⁻⁷²

2. Objectives

2.1 Main objective

The main objective of this thesis was to gain more knowledge about the effects of noise exposure among navy personnel.

2.2 Specific objectives

Paper I

- Assess the prevalence of hearing loss among Navy personnel
- Examine the association between work on board vessels in the RNoN and hearing loss among Navy personnel

Paper II

- Investigate the incidence of STS among Navy personnel between 2012 and 2014
- Identify determinants of STS among Navy personnel

Paper III

- Assess cognitive performance subsequent to noise exposure among Navy personnel on board RNoN vessels

3. Material and methods

3.1 Papers I & II

3.1.1 Study design

The cross-sectional study of paper I presents questionnaire and pure tone audiometry data from the baseline investigation of Navy personnel (April 2012 to June 2013). The longitudinal study of paper II presents pure tone audiometry data from both the baseline and the follow-up investigation as well as questionnaire data from the follow-up investigation (August 2013 and December 2014).

3.1.2 Study population

All officers, enlisted and civilians working on board RNoN vessels were invited to participate in the NHN project by answering a questionnaire and performing an audiometric test. Conscripts were not invited as their confined period of serving (usually one year) made participation in the longitudinal study difficult.

As Navy personnel primarily spend their work time at sea, data collection in this part of the project represented a challenge. Thus, in order to optimize data collection, two contact persons in the RNoN (one from the Fleet and one from the Coast Guard) were associated to the project. These two contact persons were responsible for providing a complete sailing plan for the RNoN vessels and for informing the management on board each vessel about the project. The Navy personnel were then informed about the project in plenary by the

management on board. Information was also distributed through posters put up on board most vessels (Appendix II). The contact persons were responsible for organizing a time schedule on when to perform the examinations in accordance with the time available ashore.

The examinations were performed by trained health personnel at the two Navy bases, Haakonsværn and Ramsund and at the Coast Guard base in Sortland.

When meeting for the scheduled appointment, the personnel was handed a letter of information regarding the project (Appendix II). Participation was confirmed by signing an informed consent. Prior to the audiometry examination, the participants were asked to fill out questionnaires concerning noise exposure and hearing loss, Appendix III and IV respectively.

3.1.3 Questionnaires

In the assessment of the effects of noise exposure, we used two questionnaires: a baseline questionnaire (Appendix III) and a follow-up questionnaire (Appendix IV). A questionnaire-based investigation was preferred rather than an interview-based investigation as it is more structured and time efficient. A PubMed search was made to find standardized questionnaires on risk factors for hearing loss, but without success. We chose to make use of some of the questions utilized in a large hearing survey conducted in the Norwegian county of Nord-Trøndelag (HUNT).⁷³ The baseline questionnaire was

developed to identify the effects of various potential determinants of hearing loss within a lifetime, while the follow-up questionnaire addressed possible determinants relevant within the last 12 months. The questionnaires included questions regarding vessel affiliation, work history, occupational noise exposure (past and present), non-occupational noise exposure (past and present), use of hearing protection devices (HPDs), general and ear-specific health and other exposures which might impair hearing (ototoxic chemicals or medication, use of tobacco or diving). The completed questionnaires were examined thoroughly by the trained health personnel, and ambiguous answers were clarified.

3.1.4 Pure tone audiometry

Two types of audiometers were used at baseline: Interacoustics AD226 with Amplivox Audiocups or Peltor earphones and Welch Allyn GSI with TDH 39 P earphones. The Welch Allyn GSI audiometer was used for a limited time period to replace the Interacoustics AD226 audiometer due to technical failure of the right earphone (Amplivox Audiocups). At follow-up, data were collected using Interacoustics AD 226 with Peltor earphones.

The audiometers had different lower test limits: the lower limit of Interacoustics AD226 was – 10 dB, while the lower limit of Welch Allyn GSI was + 10 dB. Both audiometers measured hearing thresholds at the following frequencies: 250, 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz. Audiometry was performed in accordance with the Norwegian Labour Inspection Authority (NLIA) instructions

on hearing examination of noise exposed workers,⁷⁴ primarily by using an automated procedure supervised by the trained health personnel. In cases of present tinnitus, already diagnosed hearing loss or uncertainty regarding measured hearing thresholds, a manual procedure was performed. The results from the audiometry were evaluated in cooperation with an occupational health physician and an otolaryngologist and referrals were made when indicated (Appendix V). Of the 772 participants included at baseline, 19 were offered referral to an otolaryngologist for testing of hearing aids, but only one of these participants asked to be referred. Four participants were referred for other reasons, such as secretory otitis. To rule out acoustic neuroma, 18 were referred to a magnetic resonance imaging (MRI) scan of the brain as they presented with tinnitus and asymmetric hearing thresholds. All MRI scans were normal.

All measurements were performed in sound booths. Ambient noise levels in these booths were measured for 15 seconds using Brüel & Kjær sound level meter Hand-Held Analyzer Type 2250. All the measured frequencies (31.5 – 8000 Hz) were in accordance with ISO 8253-1.⁷⁵ The audiometers were calibrated annually, while the sound level meters were calibrated prior to each measurement.

3.1.5 Test procedure and check list

In order to secure proper data quality, a test procedure was prepared (Appendix VI). In meetings at Haakonsværn Navy base and Sortland Coast Guard base the procedure was presented to all the trained health personnel responsible for performing examinations. The test

procedure stated that all Navy personnel except conscripts should be examined. Specific instructions were given to the health personnel performing the examination regarding distribution of the information letter, signing of the informed consent, completion of the questionnaires and audiometry performance. The test procedure specified certain exclusion criteria which should be addressed during examination. Audiometry was not performed in cases of present acute airway infections with involvement of sinuses, nose or ears. Instead, a new appointment was arranged after the participants were asymptomatic. Otoscopy was performed for all participants before audiometry. In cases of complete obstruction of the ear canal, cerumen was removed and audiometry was performed at least one week later. Exposure to loud area noise, loud workshop noise or other loud noise the last 16 hours was noted in the checklist. Participants with both recent loud noise exposure and hearing loss (defined as hearing thresholds ≥ 25 dB in either ear at 3000, 4000 or 6000 Hz) recognized during examination (interpreted as TTS) were excluded. In these cases, a new audiometry was scheduled, and the participants were informed to avoid loud noise 16 hours before the examination.

To make sure that the test procedure had been followed, all audiometric tests were followed by completion of a stepwise checklist (Appendix III and IV).

The results from the examinations were kept in a separate health record only accessible to personnel working in the Occupational

Health Service. Thus, these data were not available for evaluation of medical suitability.

3.1.6 Participants

As the total number of Navy personnel fluctuates, it was difficult to obtain a complete list. The list provided by the contact persons included 938 of the approximately 948 Navy personnel counted at the beginning of the project period. Signed consent was given by 772 participants (99% Caucasians), while 17 chose not to give consent (Figure 5). The remaining 149 did not meet for examination due to sailing, courses, time off or leave of absence/sick leave. The majority of participants at baseline were examined at Haakonsvern Navy base ($n = 581$) while the rest were examined at Sortland Navy base ($n = 191$). Data were excluded when data collection was not made in compliance with the test procedure ($n = 81$) or due to technical failure of the right earphone ($n = 110$). The 110 participants tested with defect equipment were scheduled to perform a new audiometry; however retest was only made possible for 24 participants due to deployments. Altogether 605 participants were included in the study at baseline (569 men and 36 women), thus representing the study participants in paper I (Figure 5).

Of the 605 participants included at baseline, 291 met for the follow-up examination. However, data from 65 of the 291 participants had to be excluded as examinations were not performed according to the test procedure (Figure 5). Consequently, 226 participants (217 men and nine women) were included in the follow-up described in paper II.

Loss of follow-up ($n = 314$) was mainly due to termination of service ($n = 129$) but also due to reassignment to work on shore ($n = 63$) and other reasons ($n = 122$) equivalent to the non-attendance among 149 of the Navy personnel at baseline.

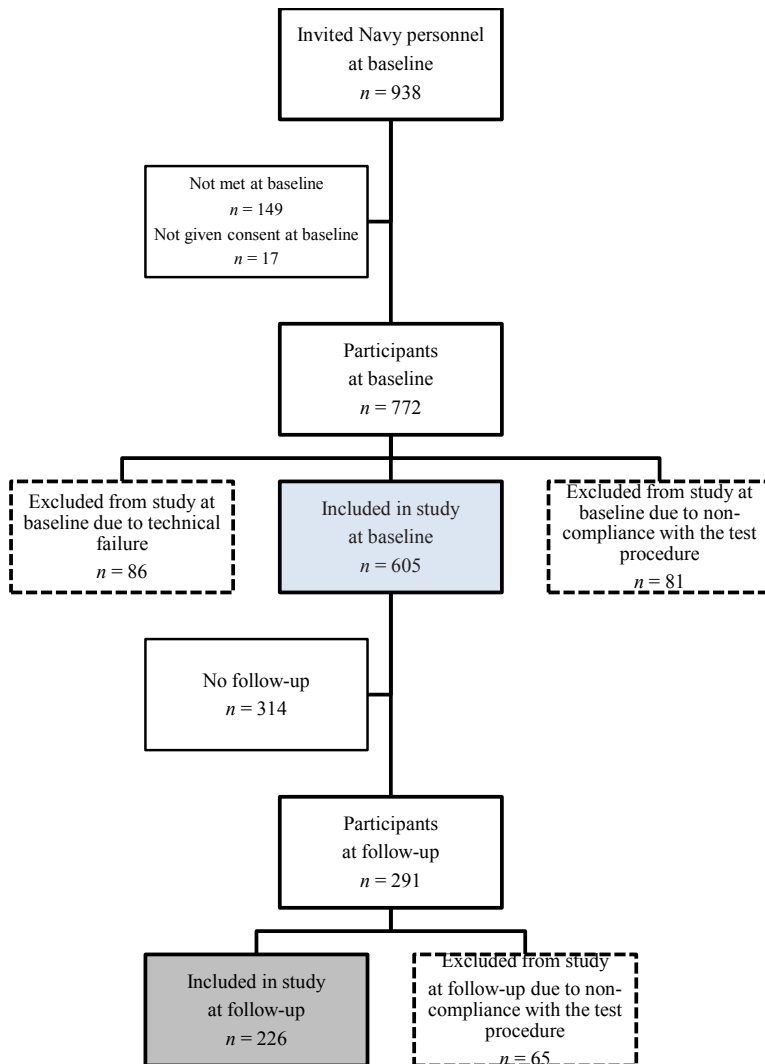


Figure 5. Baseline and follow-up examination at Haakonsværn, Sortland and Ramsund Navy bases 2012 – 2014. Blue box: Participants included in paper I, cross-sectional study 2012 – 2013. Grey box: Participants included in paper II, longitudinal study 2012 – 2014. Dotted lines indicate participants excluded from the analyses.

3.1.7 Data analysis

3.1.7.1 Paper I

Hearing loss was defined as hearing threshold levels ≥ 25 dB at 3000, 4000 or 6000 Hz in either ear. This definition was chosen as it reflects the frequencies associated with NIHL and is the one used by the NLIA.⁷⁴

Audiometry data and questionnaires from Sortland Coast Guard base and Ramsund Navy base were regularly collected by the contact person responsible for the Coast Guard and given to the trained health personnel at Haakonsvern Navy base. Gathered data from all three bases were regularly collected at Haakonsvern Navy base and then ultimately registered on a University computer by the Research Group for Occupational and Environmental Medicine.

Log binomial regression analyses (providing relative risks (RR) with 95 % confidence intervals (CI)) were performed in order to assess the association between the various determinants and hearing loss.

Expected age and gender specific median hearing thresholds were calculated as described in ISO 7029,⁷⁶ choosing the 50 percentile. The ISO standard represents a screened population similar to the selected Navy personnel without symptoms of ear disease or cerumen. However, the populations are different in that the ISO population has not been exposed to undue noise, unlike the RNoN population. Deviation from the ISO standard was calculated for all measured frequencies as follows:

Δ Hearing threshold = measured hearing threshold – expected hearing threshold according to ISO 7029

Δ Hearing threshold < 0 indicated better hearing and Δ Hearing threshold > 0 indicated poorer hearing than according to ISO 7029. The calculation was performed for each frequency and for both ears. The ear with the greatest positive Δ Hearing threshold was selected for each frequency. Linear regression analyses (providing β with 95 % CI) were performed to assess the association between the work exposure variables ‘years of work in the Navy’, ‘years on vessel(s) in the Navy’ and ‘years of sailing in the Navy’ and Δ Hearing threshold for each frequency. In these analyses, we chose to adjust for the variable ‘otitis as an adult’ from the questionnaire, as this was the only variable from the questionnaire being significantly associated with hearing loss.

Data were analysed using IBM SPSS Statistics, version 21. P-values < 0.05 were considered significant.

3.1.7.2 Paper II

The mean number of days between baseline and follow-up was 530, ranging between 242 and 959 days.

In paper II, hearing loss was defined as an average change in hearing thresholds between two audiometries $\geq + 10$ dB at 2000, 3000 and 4000 Hz in either ear, i.e. a STS. This definition which was being used in paper II is comparable to definitions used by the US Occupational Safety and Health Administration (OSHA)³⁶ and the US Navy⁷⁷ and

reflects speech comprehension. The definition was chosen to enable comparison between the US Navy and the RNoN.

Mean hearing thresholds at baseline and follow-up were calculated for each ear and every frequency. Paired sample t-test was performed to determine whether the mean hearing thresholds for the respective frequencies differed significantly between the two examinations.

Median hearing thresholds (50 percentile) as expected by ISO 7029 were calculated for all frequencies measured at the follow-up test. Paired sample t-test was used to assess whether the observed mean hearing thresholds deviated significantly from the median hearing thresholds provided by ISO 7029.

Associations between potential determinants reported in the follow-up questionnaire and STS were assessed by log binomial univariate regression analyses. Log binomial multivariate regression analyses were performed to assess associations between significant determinants of noise exposure and STS. In these analyses, RR with 95 % CI was provided.

A chi-square test was performed to compare the prevalence of hearing loss at baseline among participants who attended both examinations with the prevalence among participants who only attended at baseline. In these analyses, hearing loss was defined as hearing threshold levels ≥ 25 dB at 3000, 4000 or 6000 Hz in either ear.

Data were analysed using IBM SPSS Statistics, version 22. P-values < 0.05 were considered significant.

3.2 Paper III

3.2.1 Study design

Paper III is based on a cross-sectional study which was performed on board RNoN vessels. Cognitive performance was assessed twice during the same day; however the first test was used as a learning session. Individual noise exposure measurements were made for all participants in-between tests. A log book was kept to collect information regarding the personnel's whereabouts, and other factors which might influence performance. Figure 6 describes the test procedure briefly; details are explained in the following text.

3.2.2 Study population

Data regarding cognitive performance and noise exposure were collected by two skilled university researchers on board 24 vessels (from both the Fleet and the Coast Guard) between April 2012 and June 2013. Detailed information about the project was given to the management on board all vessels by the contact person responsible for the Fleet as well as by the university researchers a few weeks before embarking the vessels. Upon embarkation, the researchers asked the management to find two to five potential participants among the officers and enlisted personnel on board who were presumed to have different noise exposure levels. This selection was made so that the effect of different noise exposure levels on cognitive performance could be evaluated.

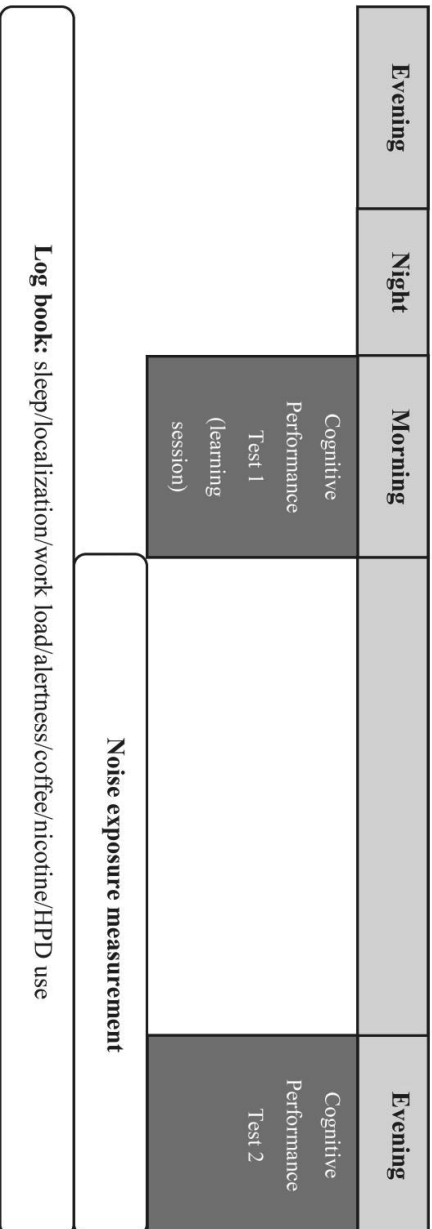


Figure 6. Test procedure. Test on cognitive performance, measurement of noise exposure and log book keeping

Information about the objectives of the study was given by the university researchers to the selected personnel who were then invited to participate in the study. A total of 116 healthy Navy personnel agreed to participate. Only one person chose not to join the study. Due to missing noise exposure registration and incomplete sleep registration ($n = 29$), the number of participants included in the study was 87 (80 men and 7 women with a mean age of 31 years). Navy personnel working on board RNoN vessels are selected by strict physical and mental health criteria, thus we expected the general health of these participants to be very good. Norwegian was the native language of all participants.

3.2.3 Cognitive performance test

Cognitive performance was assessed using a visual attention test based on the Posner cue-target paradigm. The test lasted for 4 minutes and 40 seconds and provided information on response time (RT), response accuracy and inhibition abilities^{78,79} and was programmed using E-prime 2.0, standard version. The test was performed using a laptop with a 13.3" screen. An undisturbed test location was selected in cooperation with the management on board (typically the sick bay or a cabin). The laptop was placed on a desk or a table in each test location. Ambient noise levels in each test location were measured by personal noise dosimeters during the second test.

Oral instructions were given how to perform the test immediately before the learning session.

A fixation cross hair was placed in the middle of the screen, with two frames located horizontally on each side (Figure 7 a).

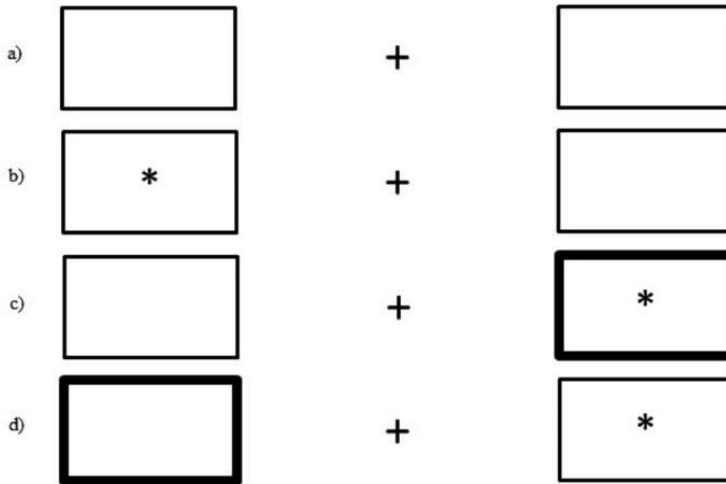


Figure 7. An overview of the cognitive performance test on Navy personnel illustrated in four separate screen displays a) – d). a) Screen display with fixation cross hair and horizontal rectangles b) Stimulus presentation without cue (no cue) c) Stimulus presentation following a valid cue d) Stimulus presentation following an invalid cue

Instructions were given to fixate on the cross hair in the middle and to respond as quickly as possible when a target stimulus (an asterisk) appeared in either of the two frames. The response was registered on the laptop's keyboard, by using the left index finger pressing “d” (target stimulus in the left frame) or the right index finger pressing “l” (target stimulus in the right frame). The letters “d” and “l” were considered optimal by their placement on the keyboard. Prior to the stimulus presentation, one of the frames could become broader (i.e. a cue). The participants were instructed not to take notice of this, and only to press the keyboard when the target stimulus appeared.

When a target stimulus appeared without a cue in advance, the presentation was called a no cue presentation (Figure 7 b). When a cue was followed by a target stimulus in the same frame, the presentation was called a valid cue presentation (Figure 7 c). This presentation would shift the attention towards the target stimulus, hence expected to decrease RT. When a cue appeared in the opposite frame of the target stimulus, the presentation was called an invalid cue presentation (Figure 7 d).

During each test, 168 target stimuli were presented. Every target stimulus was presented for 500 milliseconds (ms), while interstimuli intervals ranged from 600 to 1400 ms. Cues appeared 200 ms or 400 ms before the target stimuli was presented. The cues were distributed as follows: No cue presentations 28 times (16.7%), valid cue 112 times (66.7 %) and invalid cue 28 times (16.7 %).

RT and response accuracy were recorded on the laptop after each test was completed. Percentage of errors was calculated based on response accuracy for each stimuli presentation. Responses prior to target stimuli presentation were considered erroneous, as well as responses within 99 ms after target stimuli presentation. Responses registered with the wrong response button were also considered erroneous. Correcting an erroneous response by pressing a second time before presentation of the next stimuli was considered a correct response.

The first test was presented in the morning (learning session), while the second test was presented in the afternoon (session to be

investigated). Due to work requirements on board, 14 participants had to perform their first test in the afternoon and the second test in the evening.

3.2.4 Noise dosimeters

Personal noise exposure was assessed for each participant in the period between the first and the second test. Noise dosimeters (Brüel and Kjaer Type 4445 or 4448) were used. A dosimeter was mounted on the right shoulder of a participant immediately after the first test. Equivalent noise levels (in LAeq) were recorded every minute until the second test was completed. The participants were advised to avoid all contact with the microphone to reduce disturbance during noise exposure measurements. When putting on additional garment they were requested to displace the noise dosimeter and remount it on top of the garment. The noise dosimeters measured noise levels ranging from 50 to 120 dB(A) (type 4445) and 50 to 140 dB(A) (type 4448). The time weighing of the noise dosimeters were set at “fast” and with a 3 dB exchange rate. The noise dosimeters were calibrated by the manufacturer in January 2012. Daily calibration of the noise dosimeters was made before and after each measurement period by the use of a Sound level Calibrator Type 4231. Significant shift in calibration was not identified.

3.2.5 Log books

Printed log books were distributed to the participants in the evening on the day before testing (appendix VII). The participants were asked to fill in their log books regularly throughout the day, and they could

consult the researcher during the day if they had any questions. The log books were handed in at the end of the second test and completed under guidance from the researchers. The log book contained information regarding the amount of time spent in different locations and the number of hours of sleep the night before testing. Alertness and workload during the last shift was indicated by placing a mark on 10 cm horizontal lines. Further, number of cups of coffee, number of cigarettes or portions of moist snuff, permanent or temporary medication and use of HPD between tests was registered.

3.2.6 Data analysis

Calculation of equivalent noise levels was made using Brüel & Kjær Protector Type 7825 Version 5.0.0. A four hour registration period prior to the second test was selected as this was the minimum registration period for all participants. A five minute registration during the second test was made to attest noise levels in the test locations.

The equivalent noise levels were grouped in quartiles: < 72.6 dB(A), 72.6 – 77.0 dB(A), 77.1 – 85.2 dB(A) and > 85.2 dB(A). Data from the second cognitive performance test were analysed in order to evaluate performance after noise exposure.

Sleep was grouped in two categories: six hours of continuous sleep from 1 AM or earlier, or less than 6 hours of continuous sleep from after 1 AM. Participants who did not give information on sleep or who reported sleep in-between the two tests were excluded from the study.

Analyses were performed separately for no cue-, valid cue- and invalid cue stimuli presentations. The following covariates were included in the analyses: age, gender, self-reported alertness (0 – 10), self-reported workload (0 – 10), noise exposure in test location, number of hours of sleep the night before testing (≥ 6 hours/ < 6 hours), coffee consumption (yes/no), use of nicotine (yes/no), use of HPD the last four hours (yes/no).

Separate analyses were performed to assess the association between the covariates and noise exposure using analysis of variance (ANOVA), the chi-square test and Fisher's exact test (in case of few numbers in the exposure groups).

The association between noise exposure and RT was analysed using a multivariable general linear model (GLM). This model included the covariates that differed significantly between the noise exposure levels or were associated with RT with a p value < 0.05 for at least one of three stimuli presentations; age, alertness, workload, noise exposure in test location, number of hours of sleep the night before testing and use of HPD. We also included percentage of errors in this model, as we wanted to adjust for trade-off effects concerning speed and accuracy. The adjusted mean RT was presented with 95 % CI.

Data were analysed using IBM SPSS Statistics, version 22.0.

3.3 Ethics

The NHN project was approved by the Regional Committee of Medical and Health Research Ethics (REC South East) (case number 2012/87) and was performed in accordance with the 1964 Declaration of Helsinki and its later amendments. Information about the objectives of the project was given and participation was acknowledged by giving a written consent. Withdrawal from the study could be made at any point. Participants received no payment or any other benefit. ID numbers used in the analyses and names of the participants were kept separately and locked in safe. Only the researchers and the personnel performing the audiometries were entitled data access; consequently no data could be used for medical selection. The project was funded by the RNoN which granted full freedom to publish all results on group level. All individual results were evaluated. In case of deviation from normality, information and advice was given. Referrals were made when required (Appendix V).

4. Results

4.1 Paper I

Among the 605 participants included in the study, 31.4 % had hearing loss defined as hearing threshold levels ≥ 25 dB at 3000, 4000 or 6000 Hz in either ear. The mean age at baseline was 30 years.

The prevalence of hearing loss was significantly higher among engine room personnel (38.0 %) and navigators (37.0 %) as compared to electricians (23.6 %).

The following variables from the questionnaire were significantly associated with an increased risk of hearing loss: age, otitis as an adult and the work exposure variables: years of work in the Navy, years on vessel(s) in the Navy and years of sailing in the Navy.

When adjusted for age, gender and otitis as an adult, the work exposure variables years of work in the Navy and years on vessel(s) in the Navy were associated with hearing loss as hearing thresholds were increased at 1000 and 4000 Hz. Years of sailing was the strongest predictor of reduced hearing, showing significantly increased hearing thresholds at 1000, 3000 and 4000 Hz. No significant association was found for any of the remaining frequencies.

4.2 Paper II

Among the 226 participants in the study, 23.0 % developed STS defined as an average change in hearing threshold between baseline

and follow-up $\geq + 10$ dB at 2000, 3000 and 4000 Hz in either ear. The mean age at follow-up was 33 years.

Mean hearing thresholds for the left ear were significantly higher (i.e. poorer hearing) at follow-up than at baseline at 250 – 6000 Hz and significantly lower at 8000 Hz. Mean hearing thresholds for the right ear were significantly higher at follow-up compared to baseline at 1000 – 4000 Hz. When comparing mean hearing thresholds at follow-up with ISO 7029, the measured thresholds were significantly higher at the frequencies 250, 500, 1000, 2000, 3000, 4000 and 6000 Hz.

A significant higher risk of STS was found among participants that reported exposure to > 5 episodes of TTS during the last 12 months (RR 2.09, 95 % CI 1.21 – 3.62) compared to personnel that did not report this exposure. Personnel with current exposure to loud noise > 15 hours/week during work on board had a 2.29 times higher risk of STS. Navy personnel who had performed 1 – 200 gun shots during the last 12 months (in the Navy, in hunting or sports) had a 2.53 times higher risk of STS compared to non-shooting personnel. Exposure to > 200 shots gave increased estimates, however not significant, compared to non-shooting personnel. There was no significant association between STS and the remaining variables from the questionnaire.

In the multivariate regression analyses, the two noise exposure determinants (‘current exposure to loud noise > 15 hours/week during

work on board' and 'number of gun shots during the last year') were both associated with a higher risk of STS.

4.3 Paper III

The equivalent noise exposure level four hours prior to the cognitive performance test was between 67.2 and 99.1 dB(A) with a median level of 77.0 dB(A).

In all noise exposure groups, crude mean RT was the longest for no cue-, intermediate for invalid cue- and shortest for valid cue stimuli presentations. The highest percentage of errors was found for invalid cue presentations.

The association between noise exposure and RT was assessed by GML analyses which included covariates that differed significantly between the noise exposure levels (HPD and workload) or were significantly associated with RT (age, alertness, workload, noise exposure in test location and number of hours of sleep the night before testing). Percentage of errors was included in the analyses to adjust for speed-accuracy trade-off effects.

For no cue stimuli presentations, the adjusted RT was significantly increased in the highest noise exposure group (> 85.2 dB(A)) (RT 24.6 ms, 95 % CI 5.0 – 44.2) compared to the reference (< 72.6 dB(A)). When comparing personnel exposed to 77.1 – 85.2 with the reference group, there was a significant increase in the adjusted RT for no cue- (RT 23.8 ms, 95 % CI 6.4 – 41.3) and valid cue stimuli presentations (RT 25.0 ms, 95 % CI 7.7 – 42.4).

5. Discussion

5.1 Methodological discussion

5.1.1 Papers I & II

5.1.1.1 Study design

Two different designs were used in the study of hearing loss. The first study (paper I) was an cross-sectional study with the objective of measuring the prevalence of hearing loss and evaluating the association between work on board vessels in the RNoN and hearing loss among Navy personnel.

As hearing loss in the first study was found to be more frequent than in a normal population,²⁷ we decided to perform a longitudinal study. The finding of an association between work on board RNoN vessels and hearing loss further emphasized the necessity of performing a longitudinal study as evidence of causation is more convincing when obtained in a longitudinal design.

We originally intended to assess the one-year development of hearing loss. However, due to the inaccessibility of the participants (due to for instance sailing and attending courses) as well as reduced work force among the trained health personnel performing the audiometry, the average number of days separating baseline and follow-up was 530 (ranging from 242 – 959).

5.1.1.2 Study population

As we had limited information concerning the 149 Navy personnel who did not meet for audiometry at baseline, selection bias cannot be ruled out. However, in the letter of information it was informed that the results from the investigation would only be used for research purposes and not for medical selection. This was emphasized to reduce the risk of selection bias due to personnel with reduced hearing. To the extent such a bias exists, it will be conservative reducing the prevalence of hearing loss.

The response rate at baseline (82 %) was far higher than the response rate at follow-up (48 %). The loss of follow-up stated in paper II was mainly due to reassignment and termination of service but also absence due to sailing, courses, time off or leave of absence/sick leave. Loss of follow-up is not believed to be caused by refusal to participate in the follow-up investigation, as all had signed consent at baseline and none chose to withdraw this consent at any stage. When evaluating the baseline prevalence of hearing loss, there was no significant difference among the participants included at baseline (35 %) and the participants who did not meet at follow-up (27.8 %), $p = 0.08$. Thus, it is less likely that the loss of follow-up has influenced the results.

As the Navy personnel are selected for work on board RNON vessels by strict medical criteria, it is reasonable to believe that the results would be influenced by a healthy worker effect. Personnel with severe

hearing loss will be refused work on board RNoN vessels. Still, we found impaired hearing among Navy personnel.

5.1.1.3 Reference population

We calculated expected age and gender specific hearing thresholds based on ISO 7029.⁷⁶ This standard represents a screened population without symptoms of ear disease, obstructing ear wax or history of undue noise exposure; hence the characteristics are similar to those of the RNoN population except for noise exposure.

ISO 1999:2013 data base B3 provides median hearing thresholds based on an unscreened Norwegian population²⁷ which cannot be used to calculate exact hearing thresholds. Thus, we concluded that it would be more reasonable to make use of the ISO 7029 allowing calculation of expected age and gender specific median hearing thresholds in a screened population similar to the RNoN population. We selected to calculate median hearing threshold based on the 50 percentile. Selecting the 75 or 90 percentile would induce lower hearing thresholds in the reference population. This would make the difference between estimated and measured hearing thresholds greater, thus strengthening the results of our study. Instead of selecting a reference population, we could have adjusted for age, but concluded that it would most likely lead to over-adjustment as age and noise exposure duration are closely correlated.

Alternative control groups were considered. Selecting a control group within the RNoN (i.e. land based personnel) would be a challenge as

Navy personnel all have been exposed to noise within their Navy career. A control group of for instance office workers would be controversial due to different social and educational characteristics. We considered making use of the HUNT population as a reference population. However, as these data were collected 20 years ago and comprised a population not selected by specific criteria, this option was abandoned.

5.1.1.4 Noise exposure assessment

Noise exposure was evaluated by questionnaires in papers I and II. However, when using self-reported data, one cannot rule out incorrect reporting of noise exposure. One may suggest an overestimation of noise exposure among those who experienced noise as a problem on board, or among participants with known hearing loss, which would exaggerate associations between noise and hearing loss (i.e. recall bias).

Such associations would be more valid if based on objective noise exposure data. However, including such data in paper I was problematic as we had no such data available on historical noise exposure (i.e. on board RNoN vessels which were no longer in use). In paper II we evaluated the effects of noise exposure on hearing loss between 2012 and 2014. In this study, it would have been interesting to include personal noise measurements. However it would not be possible to perform such an extensive investigation for a study period of approximately 1.5 year. Alternatively, noise exposure could have been assessed for every job category on board the various vessels

through a task-based strategy using area measurements.^{39,80} This method could only be used under the assumption that the registered tasks would apply in general.

5.1.1.5 Questionnaires

In order to identify possible determinants of hearing loss, two questionnaire surveys were initiated. The validity of the questionnaires can be challenged by problems relating to wording or grouping of response alternatives in these non-standardized questionnaires. However, we tried to reduce this problem by engaging a RNoN officer to evaluate the questionnaires on beforehand to ensure that all questions were comprehensible. Also, the trained health personnel performing the audiometry were instructed to check that all questions were answered and to go through the questionnaires together with the participants.

Some potential determinants of hearing loss addressed in the questionnaire, were considered as confounders to NIHL and were adjusted for when indicated. Although the questionnaires were constructed to adjust for several potential confounders (e.g. cardiovascular diseases, diabetes, infections, head trauma, genetics, use of tobacco, leisure exposure to noise, diving and exposure to ototoxic medication or chemicals.⁸¹⁻⁸⁹), one cannot rule out the effects of residual confounding.

Prior studies on hearing loss among navy personnel are primarily based on data that have been collected to describe and monitor the

effects of HCPs. Few of these studies have included strict test procedures or questionnaires with possible confounding factors. Thus, the test procedure and questionnaires used in papers I and II represent a major strength to these studies.

5.1.1.6 Pure tone audiometry

Pure tone audiometry was performed for the frequencies 250, 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz as recommended by NLIA.⁷⁴ Pure tone audiometry was selected as it has been found to be a well validated and objective method for evaluating hearing⁹⁰ Alternatively, hearing abilities could be evaluated objectively by otoacoustic emissions⁹¹ or auditory brainstem response.²⁸ However, implementing such methods in the RNoN might be a methodological challenge.

A number of different errors may occur when performing audiometry.⁹² Ambient noise may produce random errors in the measurements. Thus, all audiometries were performed in sound booths. Heart beat generated sounds in the ear may represent a physiological random error. Likewise psychologically related issues would produce random errors related to illness or lacking attention or cooperation. However, in the present study of highly selected personnel, the latter sources of random error might cause minor problems.

Systematic errors may relate to the apparatus. Thus, frequent calibration and control measures are needed. A technical failure

occurred during the baseline investigation, but was discovered and handled. Due to this failure, the Interacoustics AD226 had to be replaced with a Welch Allyn GSI audiometer for a few weeks. However, the lower test limit of this audiometer was only + 10 dB, introducing a systematic error with respect to the definition of threshold. Thus, the data from this audiometer ($n = 83$) could not be used in all analyses in paper I. We do not believe that the data excluded from the analyses would have altered the results.

Systematic errors may also occur due to lack of standardized procedures. In order to secure proper data quality, we used trained health personnel and a strict test procedure with a supplementary checklist. Identical criteria for definition of thresholds were applied throughout. All data that did not comply with the criteria set by the test procedure were excluded. Hence, both the validity and reliability of the included data are considered to be good.

5.1.1.7 Data analysis

Continuous data from the questionnaires were mainly grouped by quartiles in order to obtain groups of equal size. However, this method was not applicable throughout; some data were regrouped taking their distribution into consideration; i.e. attending concerts/disco, use of mp3 player, number of episodes of impulse noise in and outside the Navy, number of gun shots (in the Navy, hunting and sports) and number of TTS episodes in and outside the Navy.

5.1.2 Paper III

5.1.2.1 Study design

In paper III, a cross-sectional design was selected and the investigation was confined to one day. Two tests of cognitive performance were performed. The first test served as a learning session, while the results from the second test were included in the analyses. Data from the first tests were not included as we had no registration of ambient noise during these tests, nor had we any information about noise exposure prior to these tests. A follow-up investigation involving repeated tests could have been initiated in order to assess the effect of noise exposure between tests. However this would be difficult due to the complex sailing pattern of the RNoN vessels.

Short-time exposure to noise has been shown to be more detrimental to cognitive performance than exposures of long duration,^{64,93} thus indicating possible adaptation. Unfortunately, as we had restricted information regarding the number of days spent at sea before data collection, we could not register changes in RT over time. For future studies, registration of time spent at sea prior to investigation is advised.

A challenge in maritime field studies is the limited possibility to control the work day of the participants. Several practical limitations concerning the registration of individual, organizational and incidental factors may conflict the results. In order to escape these practical

limitations, consecutive studies should be conducted in an experimental setting, thus being performed in a laboratory.

5.1.2.2 Study population

We do not believe that selection bias could have influenced the outcome of the study as the management on board each vessel selected participants with different noise exposure levels and had no knowledge concerning the cognitive performance abilities of the selected participants.

A strength to this study was the high response rate, as all but one person agreed to participate. It would have been desirable to include a larger number of participants, however due to limitations regarding data collection and interference with the operational capabilities on board the vessels this was difficult.

5.1.2.3 Cognitive performance test

We choose to assess cognitive performance by using a test on visual attention, as such tests have been found to be particularly sensitive to noise exposure.⁹⁴ The Posner cue-target paradigm represents a visual attention test which assesses the ability to give quick and correct reactions without being distracted by irrelevant stimuli^{78,79}; skills that are all important for navy personnel.

The simple design and short duration (< 5 minutes) make it a suitable test for field studies. However, the selected test might also have its limitations. We were not able to find an association between noise

exposure and number of errors. Contrary to our results, noise exposure have been found to affect the accuracy of performance, but not the speed of performance.⁶⁴ Previous literature has also indicated an increase in erroneous responses by increasing task duration.⁹³ Thus, one might postulate that the duration of the test might have been too short in order to be able to detect errors.

Complex task performance shows greater impairment by noise than simple tasks.⁹⁴ Hence, selecting a more complex task might have challenged the participants even more, thus further clarifying the results.

As the participants did not use HPD during completion of the test, we cannot rule out acute effects of noise exposure on cognitive performance. However, noise exposure in the test locations was equally distributed across the noise exposure groups, and we believe that noise at test site was of limited importance.

5.1.2.4 Noise exposure measurement

Objective equivalent noise levels were recorded for each participant using noise dosimeters. Noise dosimeters were also used to measure ambient noise levels in the test locations. The test location measurements were not completed for eight participants, and the missing data were replaced with the mean noise level for other participants who had completed their test in the same location.

Noise dosimeters are preferred for registration of individual noise exposure with varying exposures throughout the day.^{29,80} However,

the noise dosimeters may provide inaccurate measurements, i.a. due to accidental mechanical contact with the microphone, producing random errors. Similar problems might relate to handling of the microphone during dressing and undressing. Noise dosimeters have been used to record noise exposure also in previous maritime studies,^{69,70} but placed on the bridge or in a cabin giving a poorer registration of individual noise exposure.

Previous research has indicated deterioration of cognitive performance as a response to low-frequency noise exposure.⁷² As frequency analyses were not performed by the noise dosimeters, we cannot clarify the effect of different frequencies.

5.1.2.5 Log books

Several possible confounders regarding cognitive performance were registered in log books: age, alertness, workload, mean noise exposure in test location, gender, sleep, caffeine and nicotine use and use of HPD. However, these characteristics may not have been registered as detailed as intended.

We were not able to find an association between use of caffeine and cognitive performance. This might be explained by the fact that we did not make use of information regarding the number of cups of coffee, only whether the participants had been drinking coffee or not. An even more thorough registration of caffeine habits (tolerance and abstinence) would have been favourable.⁹⁵ However, as there were no restrictions regarding intake, we believe that the effects of tolerance

and abstinence were of minor importance in this study. The participants registered whether they had been using or had not been using HPD. A more thorough registration of HPD (type, fitting and duration of use) might also have affected the results.

Factors not recorded, such as psychological characteristics of the participants might influence cognitive performance.^{58,96} Performance can either be impaired, improved or not be affected at all when exposed to noise.⁹⁴ However, we believe that different personal characteristics were of minor importance in this study as the population was selected for work on board, thus limiting the risk of personality disorders or mental illness.

5.1.2.6 Data analysis

Registration of noise exposure was initiated just after completion of the learning session and lasted until completion of the second test. We decided to register noise exposure for four hours as this was the minimum registration period for all participants. However, we do not know whether our results might have been influenced by selecting a shorter or longer registration period.

The noise exposure measurements were grouped by quartiles. Such grouping was made as we were not able to find relevant literature suggesting cut-off values for noise exposure levels associated with cognitive performance.

To be able to adjust for number of hours of sleep, the participants were grouped in two: participants who had been sleeping continuously

for six hours or more from 1 AM the previous night and all other participants. This grouping was selected as a six hours sleep duration is considered appropriate (i.e. the anticipated health benefits exceed the negative consequences).⁹⁷

5.1.3 External validity

This thesis adds to the limited knowledge on the association between noise exposure on board navy vessels and effects among navy personnel. The presented findings might apply to navy personnel of other countries if noise exposure levels are similar. However, as literature concerning noise exposure on board navy vessels is limited,⁴⁰⁻⁴² it is difficult to conclude whether the noise levels on board RNoN vessels are similar to the noise levels on board vessels in other navies.

The presented findings may also apply to other work places with continuous noise exposure for more than 24 hours and with additional exposure to impulse noise.

5.2 Main discussion

5.2.1 Papers I & II

The occurrence of hearing loss was interpreted as high in both of the present studies, with a prevalence of hearing loss in paper I of 31.4 % and an incidence of STS in paper II of 23.0 %. A limited number of studies report on hearing loss in the navy, and few are of recent date (Table 1).

The prevalence of hearing loss found in paper I (31.4 %) is higher than in similar cross-sectional studies. In a cross-sectional study conducted in the Australian Navy, the prevalence of hearing loss among 693 navy personnel was 15.1 %.⁵⁵ In a cross-sectional study, conducted in the Thai Navy in 2009, the prevalence of hearing loss among 149 officers working on board coastal patrol boats was 22.8 %.⁵⁶ However, due to different definitions of hearing loss (Table 1) the studies and the results are not necessarily comparable.

The majority of previous research concerning hearing loss in the navy has been conducted in the US Navy through longitudinal studies.^{4,6,52-54} Incidences of STS presented in US Navy studies are quite similar to that found in paper II,^{4,5} however comparing these studies is difficult due to varying length of the observation period. In an examination of 12 492 audiometric records from personnel working on board US Navy vessels between 1987 and 1990 the incidence of STS was 29 %.⁴ A lower STS (18.1 %) was found among 54 057 navy personnel who were either working on board navy vessels or ashore between 1995 and 1999. One might suggest that the higher STS found among the US Navy personnel working on board navy vessels was caused by higher levels of noise exposure on board the vessels than on shore.

The development of hearing loss may differ between different military branches. In two studies conducted in the Swedish Army, STS incidences of 6.6 and 7.9 % were observed.^{98,99} These incidences are considerably lower than the STS incidence of 23.0 % found in our study although these conscripts were frequently exposed to high noise

levels from armoured vehicles (103 – 107 dB(A)) and firearms (156 – 184 dB(A)). The higher STS incidence found in our study might result from exposure to moderate noise levels continuously for days or weeks on board RNoN vessels. The lower incidence among Swedish conscripts might also be explained by a shorter observation period (7 – 11 months), lower average age (18 – 19 years), use of different audiometric test methods and different STS definitions.

In the present studies of hearing loss, an association between time spent on board Navy vessels and hearing loss was suggested. Results in paper I indicated a 0.48 dB increase in hearing threshold at 4000 Hz per year of sailing. The association between time spent on board Navy vessels and hearing loss was not reproduced in paper II, probably due to a short observation period. However, current exposure to loud noise was a significant determinant of STS in paper II. These findings correspond well with the previous literature. In a large US Navy investigation of audiometric results from 1982 to 2004 it was concluded that one year of work on board warships was associated with a higher risk of STS (RR 1.06, CI 1.06 – 1.07) compared to one year of work on shore (RR 1.04, CI 1.03 – 1.04).⁵⁴

In Paper I we investigated the prevalence of hearing loss by job category and found the highest prevalence among engine room personnel (38.0 %) and navigators (37.0 %) and the lowest among electricians (23.6 %). There was a significantly greater risk of hearing loss among engine room personnel (RR 1.61, CI 1.06 – 2.45) and navigators (RR 1.57, CI 1.04 – 2.38) compared to electricians. Results

from personal noise dosimeter measurements on board different vessels in the RNoN indicate that noise exposure varies by job category.³⁹ On board the frigates, a higher mean noise level was observed among engine room workers (86.5 dB(A)), than electricians (72.6 dB(A)). Thus, the varying prevalence of hearing loss found in different job categories might be explained by varying noise exposures. However, this interpretation was not valid for all job categories. For instance, although navigators were found to have a high prevalence of hearing loss, they had the lowest mean equivalent noise exposures in frigates (72.0 dB(A)), corvettes (75.6 dB(A)) and mine vessels (73.4 dB(A)).³⁹ However, the high prevalence of hearing loss found among navigators might at least partly be explained by age, as the highest mean age was found in this job category.

In a study from the Royal Thai Navy; focus was also on job categories. The high prevalence of hearing loss among Thai officers working on coastal patrol boats (22.8 %) was explained by noise exposure from the machinery (100.6 dB(A)).⁵⁶ In a US Navy and Marine Corps study as well as in our study, a higher incidence of STS was observed among enginemen (between 18.0 and 20.2 %) than among electrician groups (between 5.0 and 23.8%).^{4,5} The noise levels measured in engine rooms and in engine control rooms (in which the electricians have their work site) on board commercial vessels are quite similar to the levels on board RNoN vessels.^{43,44,46} The excess risk of hearing loss among engine room workers has also been found among Danish seafarers and fishermen; the risk of hearing loss was

2.39 times greater among engine room workers than among other seafarers.¹⁰⁰

In both paper I and II we found poorer hearing among Navy personnel than estimated by ISO 7029. This finding is in line with previous investigations in the military: Mean threshold levels for men serving in the US Navy and Marine Corps have been found to be poorer than the OSHA age-adjusted values,^{36,52} while officers in an infantry regiment of the Swedish Army have been shown to be poorer than compared to ISO 1999(1990), data base A.^{101,102}

In paper II we found an association between exposure to impulse noise from firearms and impaired hearing. However, there was no linear relationship between number of gunshots in the Navy, hunting and sports during the last 12 months and STS. The Navy personnel who had been shooting more than 200 gun shots had no significantly excess risk of STS. One might speculate that this group is more tolerant to noise and possibly more experienced (with proper use of HPD) than Navy personnel who had been shooting 1 – 200 gun shots. The excess risk of hearing loss among gun shooters has previously been described both in military and non-military studies. Brazilian military personnel exposed to noise from handguns (119 – 133 dB(C)) had significantly poorer hearing than administrative staff.¹⁰³ In a population based study, the risk of hearing loss was significantly higher among participants who had been shooting targets the last year compared to participants who had not been shooting (OR 2.00, CI 1.15 – 3.46).⁸⁸

In paper I, we found an association between work on board RNoN vessels and impaired hearing at 1000, 3000 and 4000 Hz. The audiometric curves presented in paper II showed a downward slope from 2000 Hz, a notch at 6000 Hz and improvement at 8000 Hz.

Some inconsistency in the previous literature exists regarding the effect of noise exposure on audiometric results,^{73,104,105} though all the referred studies agree on involvement of 6000 Hz when impulse noise is present. Results from the Norwegian HUNT study showed an association between occupational noise exposure and threshold shifts at 3000 and 4000 Hz, while there was an association between impulse noise (e.g. explosions and shooting) at threshold shifts at 3000 – 8000 Hz.⁷³ Impaired hearing (5 – 10 dB) at 3000, 4000 and 6000 Hz was found among industrial workers engaged in recreational shooting compared to industrial workers who did not shoot.¹⁰⁵ In a Finnish study of Army conscripts who had suffered acoustic trauma, the greatest hearing loss was found at 6000 Hz.¹⁰⁴ In paper II we also discovered involvement of the lower frequencies (500 – 1000 Hz). Similar findings were made in the Finnish study which showed that 25 % of the conscripts had hearing loss at 500 – 2000 Hz, which was likely due to exposure from cannons and explosions.¹⁰⁴

It is difficult to determine the separate contribution of continuous noise and impulse noise on different frequencies. Both exposures are likely to cause hearing damage. Exposure to impulse noise has been found to be more harmful than exposure to continuous noise,¹⁰⁶ but

the combination of these seem to induce more severe changes than one of the exposures alone.¹⁰⁷

5.2.2 Paper III

The RT among participants with the highest noise exposure (> 85.2 dB(A)) (no cue presentations) and the next highest noise exposure (77.1 – 85.2 dB(A)) (no cue and valid cue presentations) was significantly increased compared with the participants with the lowest noise exposure (< 72.6 dB(A)). There was no significant increase in RT among the highest exposed compared to the lowest exposed for valid and invalid cue presentations. This finding might relate to more extensive use of HPD among participants being exposed to > 85.2 dB(A). Unfortunately, due to incomplete recordings of individual HPD use, we were not able to adequately control for this factor and it is probably disturbing a dose-response effect of noise exposure. Contradictory to expected, mean RT was shorter for invalid cue presentations than for no cue presentations, indicating reduced cue inhibition. Though, the percentage of errors was higher for invalid cue presentations than for the other presentations. This speed-accuracy trade-off effect might be explained by presumably competitive participants.

The after-effects of noise exposure on cognitive performance have received limited attention in prior research.⁶⁵⁻⁶⁸ Our study was conducted as the need of high precision is of major importance when working on board RNoN vessels. Also the available literature regarding noise exposure and cognitive performance in relation to

work at sea is scarce with fairly inconsistent results. In a Swedish Navy study, the association between noise exposure and cognitive performance of personnel on board three coastal fleet vessels (two patrol boats and one experimental ship) was investigated.⁷² Simple RT was evaluated among the 29 participants three times a day: in the morning, at noon and in the afternoon. Noise dosimeters registered equivalent noise levels of approximately 80 dB(A) at sea and between 50 and 65 dB(A) at quay. RT was prolonged in the afternoon among participants working in the experimental ship, however most prominent at sea than at quay. This result supports our findings suggesting an association between low performance and high noise exposure. On board the patrol boats in the Swedish study, there was an inverse outcome showing shorter RT in the afternoon than in the morning, and no difference in RT at sea or at quay. As noise exposure levels on board the ships were quite similar, the prolonged RT found among participants working on board the experimental ship was explained by the low-frequency character of the noise on board.

The association between noise exposure and cognitive performance has previously been evaluated among seafarers in the offshore oil industry (three vessels) and in the short sea sector (seven vessels).⁷¹ Noise exposure was evaluated using noise dosimeters, while cognitive performance was assessed through the use of simple RT, a task on focused attention and a categorical search task.⁶⁹ In the offshore oil industry ($n = 62$), mean simple RT measured after a work shift was significantly longer among participants who had been exposed to ≥ 59

dB(A) than participants exposed to < 59 dB(A). This result is in line with our findings. In the short sea sector ($n = 177$), there was no association between RT and noise exposure, although a significant correlation was found between noise levels and the capability to encode new information on a focus attention task.⁷⁰ The inconsistent results were explained by different noise characteristics (more intermittent noise exposure on board vessels in the offshore oil industry than on board vessels in the short sea sector). Previous studies have indicated a more disruptive effect of intermittent noise than of continuous noise.^{64,93,108,109}

6. Conclusions

Through the three studies presented in this thesis more knowledge has been gained concerning health outcomes related to noise exposure on board navy vessels. Based on the objectives of this thesis the following conclusions can be made:

- The prevalence of hearing loss among Navy personnel was 31.4 %.
- The incidence of STS among Navy personnel between 2012 and 2014 was 23.0 %.
- Work on board RNoN vessels was a significant predictor of reduced hearing.
- A significant association between STS and exposure to self-reported current loud noise for more than 15 hours per week on board RNoN vessels and number of gun shots last year was found.
- The Navy personnel with the highest noise exposure performed poorer on a visual attention test than those with the lowest exposure.

7. Recommendations

Based on the conclusions presented, recommendations are suggested how to prevent future work related hearing loss among Navy personnel.

The preventive potential of reduced noise exposure should encourage the RNoN to establish a more specified and targeted HCP than present. This is important as hearing loss may have great impact on the individual worker's health and wellbeing, and may degrade operational capability and safety by interrupting communication.

The HCP should include the following elements: rules, regulations and recommendations, education and training, noise measurements, audiometry and noise-reducing measures. Although these elements are already included in the RNoN's work regarding safety and health on board vessels, they should be put in context and evaluated more systematically. In order to establish a well-functioning HCP, a dedicated leader of the programme is required. The Research Group for Occupational and Environmental Medicine has made recommendations concerning the contents of a HCP in a separate report related to the total project.¹¹⁰ A short description of the recommendations is given Table 2.

Table 2. A short description of the recommendations given to the RNoN on the contents of a hearing conservation programme (HCP)

Rules, regulations and recommendations	<ul style="list-style-type: none"> - Noise exposure limits, methods for assessing noise exposure on board RNoN vessels and methods for performing audiometry exist but must be followed more systematically
Education and training	<ul style="list-style-type: none"> - Navy personnel should be given more systematic education and training on the effects of noise exposure and how to protect themselves - The quality of education and training should be evaluated
Noise measurements	<ul style="list-style-type: none"> - The RNoN should ensure that noise measurements are made also in the future
Audiometry	<ul style="list-style-type: none"> - Navy personnel should have their hearing evaluated by annual audiometry - Navy personnel with NIHL should receive sufficient follow-up - Audiometry results should be assessed on a group level in order to evaluate the effectiveness of the HCP
Noise-reducing measures	<ul style="list-style-type: none"> - Technical measures should be implemented to reduce noise levels on board RNoN vessels - Organisational measures should be applied on board RNoN vessels (e.g. restrictions in working hours) - Make sure that HPD is of high quality, being individually fitted and properly used in order to reduce the effects of noise exposure

8. Future research

Even though it has already been concluded that important knowledge has been gained as a result of the present thesis, further research is still warranted. Future research may address the following topics:

- The association between noise exposure on board navy vessels and hearing loss should be investigated by assessing individual noise exposure. This can be made by a task-based strategy using area measurements.
- The separate contribution of impulse noise and continuous noise exposure on board navy vessels should be further clarified.
- The effects of long term noise exposure (> 24 hours) on hearing should be further investigated both in the navy of other countries and in other workplaces.
- Cognitive performance subsequent to noise exposure should be further evaluated in field studies. In future studies, data should be collected for several days and include frequency analysis of noise, alternative methods for assessing cognitive performance and a more thorough registration of the possible confounding factors.
- Cognitive performance subsequent to noise exposure should be further evaluated in experimental laboratory studies which provide more standardized settings than field studies.

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Hearing loss in the royal Norwegian navy: a cross-sectional study

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Abstract

Objectives Prior studies have indicated a high prevalence of noise-induced hearing loss (NIHL) among Navy personnel; however, it is not clear whether this is caused by work on board. The present study aimed to assess the prevalence of hearing loss among Navy personnel in the Royal Norwegian Navy (RNoN), and to investigate whether there is an association between work on board RNoN vessels and occurrence of hearing loss.

Methods Navy personnel currently working on board RNoN vessels were recruited to complete a questionnaire on noise exposure and health followed by pure tone audiometry. Hearing loss was defined as hearing threshold levels ≥ 25 dB in either ear at the frequencies 3,000, 4,000 or 6,000 Hz. Hearing thresholds were adjusted for age and gender using ISO 7029.

Results The prevalence of hearing loss among Navy personnel was 31.4 %. The work exposure variables: years of work in the Navy, years on vessel(s) in the Navy and years of sailing in the Navy were associated with reduced hearing

after adjusting for age, gender and otitis as an adult. Among the work exposure variables, years of sailing in the Navy was the strongest predictor of reduced hearing, and significantly reduced hearing was found at the frequencies 1,000, 3,000 and 4,000 Hz.

Conclusions Our results indicate that time spent on board vessels in the RNoN is a predictor of reduced hearing.

Keywords Audiometry · Hearing conservation · Hearing loss · Noise exposure · Noise-induced hearing loss

Introduction

Noise-induced hearing loss (NIHL) is considered to be one of the most prevalent work-related diseases worldwide. A worldwide analysis states that 16 % of disabling hearing loss in adults is attributable to occupational noise exposure (Nelson et al. 2005).

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Studies on occurrence of hearing loss among Navy personnel are infrequent, and to our knowledge, no studies have been published recently (Trost and Shaw 2007; Wolgemuth et al. 1995). Previous studies from the USA have reported noise exposure to be the most prevalent occupational health hazard in the US Navy (Bohnker et al. 2002b), and deteriorated hearing thresholds have been found among 29 % of Navy personnel (Wolgemuth et al. 1995).

Prior studies on hearing loss among Navy personnel have primarily been based on data collected with the purpose of describing and monitoring effects of hearing conservation programs, and hearing has not always been examined systematically in these studies. Few studies have included strict protocol-based measurements, and they have not always considered other potential causes of hearing loss, as for instance non-occupational noise exposure, prior ear disease or exposure to ototoxic medication. The relationship between hearing loss and work on the vessels has not been clearly documented in prior studies.

Navy operations at sea cause noise levels on board RNoN vessels that are higher than recommended limit values (Irgens-Hansen et al. 2013; Koefoed 2011), and in a RNoN study on health and work environment, self-reported prevalence of reduced hearing was 24 % (Moen et al. 2008).

The aim of this study was to assess the prevalence of hearing loss and examine the association between work on board vessels in the RNoN and hearing loss among Navy personnel.

Methods

Study population

From April 2012 to June 2013, Navy personnel currently working on board RNoN vessels were asked to participate in a cross-sectional study on noise and hearing by completing an audiometric test and a questionnaire on noise exposure and health. The Navy personnel recruited included officers, enlisted personnel and civilians; 99 % were Caucasians. The total number of Navy personnel fluctuates, and a complete list was not possible to obtain; however, 938 (of the approximately 948 Navy personnel counted at the beginning of the project period) were asked to take part. Information about the study was given in plenary by the management on board each vessel and was also provided through a written letter handed out prior to examination. The study was carried out by trained personnel at the two naval bases (Bergen and Sortland), supervised by a researcher from the University of Bergen. A total of 581 participants were examined in Bergen, while 191 were examined in Sortland.

Questionnaire

The questionnaire comprised questions regarding occupational and non-occupational factors which could possibly induce hearing loss (Table 1). This included questions about work history, current and prior noise exposure at work and during leisure time, use of hearing protection, general and ear-related medical history, use of ototoxic medication, diving, exposure to ototoxic chemicals, smoking and use of moist snuff. The completed questionnaires were assessed by the personnel who examined the hearing, and participants were asked to clarify ambiguous or missing answers.

Pure tone audiometry

A stepwise test protocol was developed in cooperation with an otolaryngologist and was followed by the personnel performing the audiometry. A checklist was used to ensure that all steps in the procedure were followed. Otological examination was performed prior to audiometry. In cases of complete ear canal obstructions, cerumen was removed and a new appointment was made at least one week later. Pure tone audiometry was done using Interacoustics AD226 with Amplivox Audiocups or Peltor earphones with a lower test limit of -10 dB, or with Welch Allyn GSI with TDH 39 P earphones with a lower test limit of $+10$ dB. Background noise in the two booths used was measured (15 s) with Brüel & Kjær sound level meter Hand-held Analyzer Type 2250. The background noise was in accordance with ISO 8253-1 (2010) for all frequencies (in the range 31.5–8,000 Hz) with the highest L_{\max} at 55 dB (31.5 Hz). The frequencies selected for audiometry were the following: 250, 500, 1,000, 2,000, 3,000, 4,000, 6,000 and 8,000 Hz. The equipment was calibrated prior to audiometry (ISO 8253-1 2010).

An automated procedure was used, but if there was uncertainty regarding measured hearing thresholds, ongoing tinnitus or former recognized hearing loss, manual audiometry was performed. Individual noise exposure within the last 16 h prior to audiometry was evaluated by a checklist that contained the following choice of statements regarding recent noise exposure: “No loud noise exposure,” “Loud area noise exposure,” “Loud workshop noise exposure” and “Other loud noise exposure.” Navy personnel who reported being highly exposed to noise the previous 16 h (who had stayed in loud area noise; e.g. engine room or workshop) and who had a hearing threshold ≥ 25 dB in either ear at 3,000, 4,000 or 6,000 Hz were excluded. In order to be included in the study, a new audiometry had to be conducted when they had not been exposed to loud noise the previous 16 h. Audiometry was not performed in cases of present acute airway infections with additional sinus,

Table 1 Questions and response alternatives in a questionnaire about noise exposure and health given to Navy personnel in Norway, 2012–2013

	Question	Response alternatives	
Work history	Working position	Free text ^b	
	Years of work in the Navy	Number of years ^a	
	Years on vessel(s) in the Navy	Number of years ^a	
	Years of sailing in the Navy	Number of years ^a	
Current and prior occupational noise exposure	Have you been exposed to impulse noise (explosions etc.) in your work in the Navy without using hearing protection?	Yes/no	Number of times ^a
	Have you had temporary reduced hearing, fullness or ringing in the ears after being noise-exposed during the last year?	Yes/no	Number of times ^a
	Have you used/do you use hearing protection in high noise areas on board vessels in the Navy in these periods?	2010–2012 2000–2009 <2000	Yes, most of the time Sometimes No Of no relevance
	Do you use hearing protection while shooting?	Yes, most of the time Sometimes No	
Current and prior non-occupational noise exposure	Have you been hunting/are you hunting?	Yes/no	Number of seasons ^a
	Do you use hearing protection while hunting?	Yes, most of the time Sometimes No	
	Number of gunshots last year (in the Navy, hunting and sports)	Number of shots ^a	
	Have you played/do you play in a band?	Yes/no	Number of years ^a
	How often do you attend concerts/disco etc. playing loud music?	Weekly ^c Sometimes/month ^c Sometimes/year Seldom/never	
	Do you currently use Mp3 player etc. with plugs/phones?	>6 h/week ^d 3–6 h/week ^d 1–2 h/week Seldom/never	
Medical history	Have you ever had any of these diseases?	Heart disease Hypertension Diabetes, type 2	Yes No
	Did you have otitis as a child (0–17 years)?	Yes/no/I don't know	
	Have you had otitis as an adult (from the age of 18 years)?	Yes/no/I don't know	
	Have you ever been hospitalized due to head injury?	Yes/no	
	Have/had any in you closest family reduced hearing?	Mother/father/children/ siblings/none close	
	Have you used ototoxic medication earlier (diuretics, broad spectrum antibiotics, cytotoxins)?	Yes/no/I don't know	
Other occupational or non-occupational exposure	Have you been diving?	Yes, professional in the Navy Yes, professional outside the Navy Yes, leisure diving No, never	
	Have you had ear damage following diving (being treated in pressurized tank due to the ear damage)?	Yes/no	
	How often do you work with organic solvents (paint/washing with thinner)?	Daily Weekly Monthly Seldom/never	
	Have you smoked/do you smoke?	Yes, daily Sometimes Earlier No	

Table 1 continued

Question	Response alternatives
Have you used moist snuff/do you use moist snuff?	Yes, daily Sometimes Earlier No

^a Continuous variables were grouped by quartiles

^b The alternative “working position” was grouped into seven job categories

^c The alternatives “weekly” and “sometimes/month” were merged due to low numbers to the alternative “≥sometimes/month”

^d The alternatives “>6 h/week” and “3–6 h/week” were merged due to low numbers to the alternative “≥3 h/week”

nose or ear affection, and testing was postponed until the participant became asymptomatic. In cases of inadequate completion of the test protocol, the results were excluded. All results were evaluated by the researcher in cooperation with an otolaryngologist, and referral to supplementary tests was made when indicated.

A total of 772 gave their consent to join the study. In spite of a test regime controlling the audiometer and earphones, an unstable wire connection on the right earphone (Amplivox Audiocups) was discovered after some weeks of testing, affecting 110 measurements conducted in Bergen. In 24 of these cases, an additional audiometry was performed by qualified personnel assigned to the project. We were not able to retrieve the remaining 86 participants for an additional audiometry. Due to this technical failure as well as to insufficient compliance with the test protocol, results from a total of 167 participants had to be excluded, leaving 605 participants included in the study (Fig. 1).

Analysis

Results are presented as descriptive statistics, using percent, mean, standard deviation (SD) and Pearson correlation coefficient (R).

Participants were categorized into job categories according to working position on board. Hearing loss was defined as hearing threshold levels ≥ 25 dB in either ear at 3,000, 4,000 or 6,000 Hz. Continuous variables of potential determinants of hearing loss were categorized in quartiles. Log binomial regression provided relative risks (RR) with 95 % confidence intervals (CI) of hearing loss among the different determinants. Only determinants with significant impact on hearing were presented.

In order to adjust for the influence of age and gender on hearing, a new variable was constructed. Based on ISO 7029 (2000), we calculated the age and gender-specific hearing threshold and compared this expected value with the respective participants’ measured hearing thresholds. In this calculation, the 50 percentile hearing threshold provided in the ISO standard was chosen. Deviation from the expected hearing threshold value was calculated as:

$$\Delta \text{Hearing threshold} = \text{measured hearing threshold} \\ - \text{expected hearing threshold according to ISO 7029}$$

A Δ Hearing threshold <0 indicated a better hearing than according to ISO 7029, Δ Hearing threshold = 0 indicated hearing equal to ISO 7029, while Δ Hearing threshold >0 indicated poorer hearing than according to ISO 7029. This calculation was made for each frequency for both ears, and for each participant, the poorest Δ Hearing threshold of the two ears for each frequency was chosen.

The association between the work exposure variables (years of work in the Navy, years on vessel(s) in the Navy and years of sailing in the Navy) and Δ Hearing threshold for each frequency was analyzed by linear regression providing β and 95 % CI. The results were adjusted for otitis as an adult, which was the only variable apart from age with significant negative impact on hearing in our data. This analysis was only completed for the 522 participants tested with the Interacoustics AD226 audiometer, thus excluding those who were tested with the audiometer with +10 dB as the minimum test level. In a separate linear regression analysis, we excluded participants with prior otitis as an adult instead of adjusting for this. This analysis was completed for 453 participants tested with the Interacoustics AD226 audiometer.

Statistical significance was set at $p < 0.05$. The data were analyzed using IBM SPSS Statistics, version 21.

Research ethics

The study was performed in accordance with the 1964 Declaration of Helsinki and its later amendments. The study protocol was approved by the Regional Committees for Medical and Health Research Ethics, REC South East. The participants were informed about the objectives and conditions of the study and gave their informed consent. The participants received no payment for participating in the study, and they could withdraw from the study at any point. Individual data from the study could not be used as a basis for medical selection of candidates. The Royal Norwegian Navy permitted all available results on group level to be published.

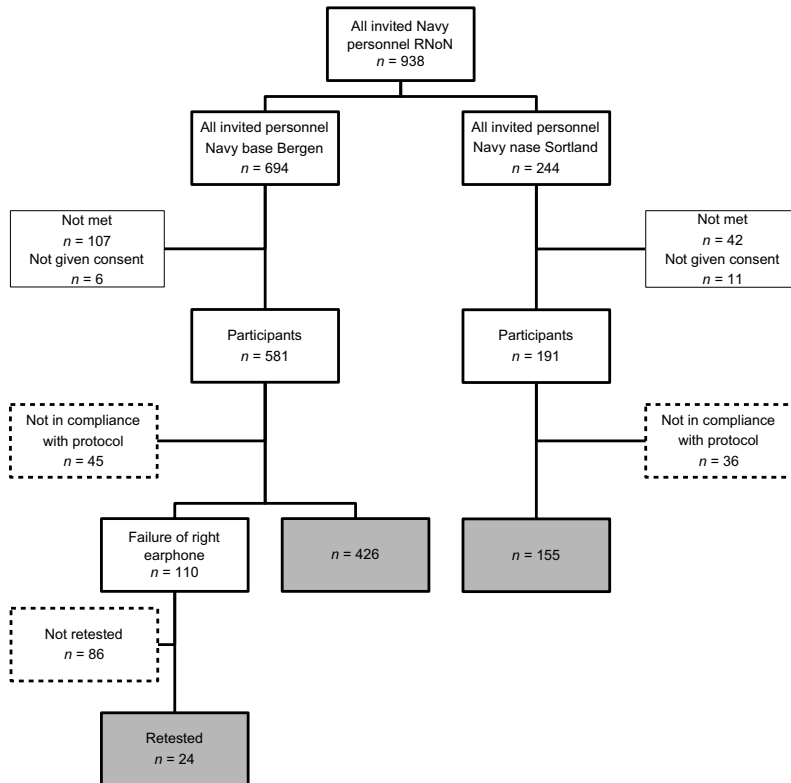


Fig. 1 Flowchart describing a study among Navy personnel in Norway, 2012–2013. *Gray boxes* indicate participants included in the analysis ($n = 605$). *Dotted lines* indicate participants excluded from the analysis ($n = 167$)

Results

The study population consisted of 605 participants, of which 569 were male and 36 female. The mean age of the participants was 30 years, with a range from 19 to 62 years. A total of 190 participants (31.4 %) had hearing loss defined as hearing threshold levels ≥ 25 dB in either ear at 3,000, 4,000 or 6,000 Hz.

The prevalence of hearing loss was significantly higher among navigators (37.0 %) and engine room personnel (38.0 %) than electricians (23.6 %) (Table 2).

The log binomial regression ($n = 605$) showed that hearing loss was significantly associated with age, the work exposure variables: years of work in the Navy, years on vessel(s) in the Navy and years of sailing in the Navy, otitis as an adult, attending concerts/disco and use of Mp3 player (Table 3).

The prevalence of hearing loss was 50.3 % among Navy personnel aged above 33 years, and 23.0 % among

those aged below 24 years (Table 3). Navy personnel who had sailed for more than three years in the Navy had a 46.4 % prevalence of hearing loss, while the prevalence was 26.4 % among the Navy personnel who had sailed in the Navy for less than one year (Table 3). However, the work exposure variables were all significantly inter-correlated (Pearson correlation) with age: years of work in the Navy ($R = 0.88$, $p < 0.001$), years on vessel(s) in the Navy ($R = 0.85$, $p < 0.001$) and years of sailing in the Navy ($R = 0.80$, $p < 0.001$). Among the 77 participants who had experienced otitis as an adult, 50.6 % had hearing loss (Table 3). Two determinants were associated with a reduced risk of hearing loss: attending concerts/disco and using Mp3 player (Table 3). No association was observed between hearing loss and the following variables from the questionnaire: impulse noise, use of hearing protection, work with organic solvents, diving, heart disease, hypertension, diabetes, otitis as a child, reduced hearing in closest family, episodes of temporary reduced hearing, admittance

Table 2 Prevalence and relative risk (RR) of hearing loss by job category in a study of 605 Navy personnel in Norway, 2012–2013

Job category	Total number ^a <i>n</i>	Mean age (min–max)	Hearing loss ^b <i>n</i> (%)	RR	95 % CI
Electrician	106	28 (20–48)	25 (23.6)	1 (ref)	
Work on deck	88	26 (19–46)	22 (25.0)	1.06	0.64–1.75
Work in ships office	36	29 (20–47)	10 (27.8)	1.18	0.63–2.21
Cook	25	26 (19–53)	8 (32.0)	1.36	0.70–2.64
Work in operation room	118	29 (19–50)	40 (33.9)	1.44	0.94–2.20
Navigator	119	34 (23–62)	44 (37.0)	1.57*	1.04–2.38
Engine room personnel	108	31 (19–54)	41 (38.0)	1.61*	1.06–2.45

Log binomial analysis

* Statistical significance

^a Job category was missing for five participants

^b Hearing loss defined as ≥ 25 dB in either ear at 3,000, 4,000 or 6,000 Hz

to hospital due to head injury, ototoxic medication, use of cigarettes, use of moist snuff, hunting and number of gunshots the previous year or playing in a band (data not shown).

Using the age and gender-adjusted variable Δ Hearing threshold and adjusting for otitis as an adult in a linear regression model ($n = 522$), the hearing threshold level increased significantly for all the three work exposure variables at 1,000 and 4,000 Hz (Table 4). The hearing threshold level at 3,000 Hz was significantly increased only for the work exposure variable years of sailing in the Navy. Among the three work exposure variables, years of sailing in the Navy was the strongest predictor of impaired hearing. There was no statistically significant association between the work exposure variables and hearing threshold levels at 6,000 Hz (a frequency often associated with NIHL), nor at the frequencies 250, 500, 2,000 or 8,000 Hz. In the separate analysis in which participants with prior otitis as an adult were excluded ($n = 69$), the hearing threshold level was significantly increased for the work exposure variable years of sailing in the Navy at 1,000, 3,000 and 4,000 Hz (data not shown). Years on vessel(s) in the Navy was associated with a significantly poorer hearing threshold at 4,000 Hz. Years of work in the Navy was not associated with impaired hearing thresholds in this analysis.

Discussion

The prevalence of hearing loss among Navy personnel was 31.4 %. Hearing loss was associated with the work exposure variables: years of work in the Navy, years on vessel(s) in the Navy and years of sailing in the Navy, as well as age and otitis as an adult. When adjusting for age, gender and otitis as an adult, higher hearing thresholds at 1,000 and 4,000 Hz were found when assessing the work

exposure variables. Of the three work exposure variables, years of sailing in the Navy was the strongest predictor of hearing loss in our study and suggests that work on board RNoN vessels is detrimental to hearing.

Similar results were also found when excluding participants with prior otitis as an adult. However, for years of employment and years on vessel(s) in the Navy, this association was weaker and might be explained by the smaller sample size when excluding those with prior otitis as an adult. Using Mp3 player and attending concerts/disco seemed to have a positive impact on hearing. This finding might be related to the assumption that those who listen to loud music may tolerate the noise exposure, hence not developing hearing loss. Another explanation can be that those who already have developed hearing loss give up attending concerts/disco and listening to Mp3 player in order to avoid further deterioration of hearing. However, usage of Mp3 player and attending concerts was inversely associated with age and years of employment and the observed association may therefore have been confounded. The prevalence of hearing loss was significantly higher among navigators and engine room personnel than among electricians, suggesting that the noise exposure varies with job category.

Hearing loss can be classified in numerous ways, rendering comparison of hearing loss between different studies a challenge (Rabinowitz et al. 2012). Frequencies most important for speech discrimination can be emphasized (e.g., the U.S. Navy), while our definition is based on frequencies associated with NIHL. The U.S. Navy uses “significant threshold shift” (STS), which is defined as a change in hearing threshold relative to the initial reference audiogram of 10 dB or more averaged over 2,000, 3,000, and 4,000 Hz, in either ear (DoDI 6055.12 2013).

As an example, a U.S. study has stated that the STS prevalence would be higher if using the criteria set by the

Table 3 Significant determinants with effect on hearing, measured in 605 Navy personnel in Norway, 2012–2013

Determinant	Hearing loss n (%)	Normal hearing n (%)	RR	95 % CI
Age ^b	<24 years (ref)	42 (23.0)	141 (77.0)	1
	24–27 years	29 (25.0)	87 (75.0)	1.09 0.72–1.65
	28–33 years	39 (26.5)	108 (73.5)	1.16 0.79–1.69
	>33 years	80 (50.3)	79 (49.7)	2.19* 1.61–2.98
Years of work in the Navy ^b	0–2 years (ref)	30 (21.9)	107 (78.1)	1
	2.1–5 years	39 (26.2)	110 (73.8)	1.20 0.79–1.81
	5.1–11 years	42 (26.9)	114 (73.1)	1.23 0.82–1.85
	>11 years	78 (48.4)	83 (51.6)	2.21* 1.55–3.15
Years on vessel(s) in the Navy ^b	0–2 years (ref)	49 (24.1)	154 (75.9)	1
	2.1–4 years	35 (29.7)	83 (70.3)	1.23 0.85–1.78
	4.1–9 years	32 (22.2)	112 (77.8)	0.92 0.62–1.36
	>9 years	73 (52.9)	65 (47.1)	2.19* 1.64–2.93
Years of sailing in the Navy ^b	<1 year (ref)	73 (26.4)	203 (73.6)	1
	1.1–3 years	28 (21.7)	101 (78.3)	0.82 0.56–1.20
	>3 years	85 (46.4)	98 (53.6)	1.76* 1.37–2.26
Otitis as an adult	No (ref)	139 (29.1)	338 (70.9)	1
	Yes	39 (50.6)	38 (49.4)	1.74* 1.34–2.26
	I don't know	12 (24.0)	38 (76.0)	0.82 0.49–1.38
Concerts/disco	Seldom/never (ref)	57 (45.6)	68 (54.4)	1
	Sometimes/year	76 (29.8)	179 (70.2)	0.65* 0.50–0.86
	≥Sometimes/month	57 (25.6)	166 (74.4)	0.56* 0.42–0.75
Mp3 player	Seldom/never (ref)	95 (38.3)	153 (61.7)	1
	1–2 h/week	49 (26.3)	137 (73.7)	0.69* 0.52–0.92
	≥3 h/week	46 (27.1)	124 (72.9)	0.71* 0.53–0.95

Log binomial analysis
 * Statistical significance
^a Hearing loss: ≥25 dB in either ear at 3,000, 4,000 or 6,000 Hz
^b Continuous variables are divided in quartiles

Table 4 Age and gender-adjusted (ISO 7029) Δ Hearing threshold related to years of noise exposure among 522 Navy personnel in Norway, 2012–2013

Work exposure	Audiometry frequency (Hz)							
	1,000		3,000		4,000		6,000	
	β	95 % CI	β	95 % CI	β	95 % CI	β	95 % CI
Years of work in the Navy	0.11*	0.02, 0.21	0.05	−0.05, 0.16	0.15*	0.03, 0.28	−0.04	−0.20, 0.12
Years on vessel(s) in the Navy	0.19*	0.07, 0.31	0.10	−0.04, 0.23	0.24*	0.07, 0.40	−0.07	−0.28, 0.15
Years of sailing in the Navy	0.35*	0.17, 0.54	0.26*	0.05, 0.47	0.48*	0.22, 0.73	−0.12	−0.45, 0.21

Adjusted for otitis as an adult
 Linear regression analysis with β in dB/year
 * Statistical significance

Occupational Safety and Health Administration (OSHA) rather than using those set by the U.S. Navy (Wolgemuth et al. 1995).

The prevalence of hearing loss in the present study was 31.4 %. In a previous study, self-reported hearing loss was prevalent among 24 % of RNoN personnel (Moen et al. 2008). In contrast only 3 % of the population in a national population health survey reported hearing loss (Norway 2003) and the prevalence of disabling hearing loss among

inhabitants in a Norwegian county was 10.3 % (Engdahl and Tamsb 2010). In studies based on data from the U.S. Navy Hearing Conservation Program, the rate of total STS varied between 18.1 % (Bohner et al. 2002b) and 29 % (Wolgemuth et al. 1995). The higher prevalence of hearing loss in our study suggests that the hearing loss can be attributed to work on board RNoN vessels.

We found an association between reduced hearing and work on board navy vessels. In a study comparing hearing

thresholds in U.S. Navy and Marine Corps with OSHA age-corrected values of hearing thresholds (Bohnker et al. 2002a), it was concluded that men in Navy and Marine Corps had higher threshold levels than according to OSHA. Another study reported that working on board surface warships was more damaging to hearing than work at shore duty stations (Trost and Shaw 2007), and an increased risk of hearing impairment was indicated in a study among flight deck personnel and engine room workers on an aircraft carrier compared with administrative personnel (Rovig et al. 2004). The relationship between noise exposure on board Navy vessels and reduced hearing seen in prior studies is in line with our findings.

In the present study, we found an association between noise exposure and higher hearing thresholds at 1,000–4,000 Hz but not at 6,000 Hz. It has been reported that hearing loss appears differently depending on whether the noise exposure is continuous or results from impulse noise, like explosions and firing cannons. Continuous noise exposure tends to result in notching at 4,000 Hz (McBride and Williams 2001). Two studies which described exposure to acoustic trauma among Finnish conscripts and Finnish surviving suicide bomb victims both found the poorest hearing thresholds at 6,000 Hz (Mrena et al. 2004; Ylikoski 1989). However, this is only partly in line with findings from the larger Norwegian study, which observed approximately equal hearing thresholds at 3,000, 4,000, 6,000, and 8,000 Hz among men exposed to impulse noise (Tambis et al. 2006). Thus, based on prior literature, it is difficult to conclude whether the reduced hearing found in our study is caused by the continuous noise exposure on board or by impulse noise.

The highest prevalence of hearing loss was seen among engine room personnel (38.0 %). Comprehensive noise level measurements on board Navy vessels have barely been reported; however, studies from commercial vessels have shown that noise levels in engine rooms range from around 90 to 110 dB(A) (Neitzel et al. 2006; Svendsen and Børresen 1999; Turan et al. 2011). In a study among Danish seafarers and fishermen, the engine room personnel had a 2.39 times greater risk of hearing loss compared with other seafarers (Kaerlev et al. 2008). In U.S Navy studies the prevalence of STS among enginemen varies between 18.0 and 20.2 % (Bohnker et al. 2002b; Wolgemuth et al. 1995). The high prevalence of hearing loss among engine room personnel seen in our study might be due to high noise levels in engine rooms on board RNoN vessels.

The lowest prevalence of hearing loss in our study was seen among electricians (23.6 %). Noise levels in the engine control room (where electricians have their work site) of ferries, cargo ships and westamarans range from around 70 to 90 dB(A) (Svendsen and Børresen 1999). These levels are lower than the levels in the engine rooms

(Neitzel et al. 2006; Svendsen and Børresen 1999; Turan et al. 2011), but may still represent a hazard to hearing for sensitive individuals. Previous studies have also shown that electricians have a low prevalence of hearing loss, even lower than in our study. A U.S. Navy study comparing rates of STS found the lowest value among “Electronics technicians” (5.0 %) (Wolgemuth et al. 1995). Another U.S. Navy study which compared rates of STS among Navy and Marine Corps found STS prevalence ranging from 15.8 to 23.8 % among electrician groups (Bohnker et al. 2002b). The somewhat higher prevalence of hearing loss among electricians in our study might be due to higher noise levels in engine control rooms on board RNoN vessels than in the previously studied vessels.

The response rate in this study was high (81.4 %); however, the participation rate was only 63.8 %. This was due to the fact that data were collected in accordance with a stringent protocol. There is no reason to believe that the excluded participants differ from the ones included. We have limited information about the 149 who did not meet for examination and the 17 who did not give consent to participate; hence, we cannot rule out that these non-responders differed from the responders.

Few previous studies on hearing loss among Navy personnel have provided information on confounding factors that might be responsible for hearing loss (Henselman et al. 1995). In our study, a questionnaire regarding occupational and non-occupational noise exposure and other possible determinants of hearing loss was used, which made it possible to adjust for non-occupational determinants in the analysis.

All invited personnel were informed that individual data would not be used to assess medical skillfulness, with criteria for hearing thresholds that must be fulfilled in order to be allowed work on board. Furthermore, there is no reason to believe that recorded hearing thresholds have been biased by participants striving to get a result adequate to be allowed to work on board.

We chose to use ISO 7029 (2000) as a reference to hearing thresholds in the general population. One alternative could be to age adjust in the log binomial analysis, but this would introduce an over-adjustment, as age and years of noise exposure are closely correlated. Hearing loss is present in the youngest age-group (<24 years), suggesting that hearing loss in this population is probably primarily caused by noise exposure and less by aging. The ISO 7029 consists of a screened population free of all symptoms of ear disease, without obstructing wax and without undue history of noise exposure, hence similar to our population with the sole exception of noise exposure (ISO 7029 2000). We chose to calculate the expected hearing thresholds using the 50 percentile, although one could defend choosing 75 or 90 percentiles (acquiring lower hearing

thresholds), as our population was screened before enrollment, and one would expect a better hearing than for the population in general. However, choosing these percentiles would make the difference between estimated and measured hearing thresholds even greater, strengthening the results of our study. An alternative to choosing ISO 7029 as a reference was ISO 1999, data base B (ISO 1999 2013), which is based on a Norwegian population and presents hearing threshold levels as a function of age of an unscreened population. However, as personnel are screened when enrolled in the Navy, we chose to compare with the screened population of ISO 7029 instead. As we wished to adjust hearing thresholds at an individual rather than on a group level, we found that ISO 7029 was the preferable reference material.

Although we found coherence between years of sailing in the Navy and impaired hearing, the cross-sectional study design cannot clarify cause and effect.

In the RNoN today, no definite protocol is established on how to follow up personnel with recognized hearing loss. We hope that this study, stating a high prevalence of hearing loss, will contribute to further awareness of the noise problem on board. Noise measurements and subsequent protection against high noise levels should be implemented, and a hearing conservation program should be established in order to improve working conditions on board. As the population is young, the benefit from prevention is great and hearing can still be protected and preserved.

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Conflict of interest The authors declare that they have no conflict of interest.

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Maximum allowed noise levels in accordance with the Royal Norwegian Navy Standard Requirements and Regulations (NRAR)

Locations	At anchor or at quay with own electrical supply		Normal cruising		Maximum permanent speed	
	dB(A)	NRC*	dB(A)	NRC*	dB(A)	NRC*
Wheelhouse (Pilothouse, Bridge)	60	55	60	55	60	55
Crew cabins (staterooms, berthing, sanitary spaces)	50	45	60	55	60	55
Crew public spaces					65	60
Hospital (medical, dental, first aid centre)	50	45	60	55	60	55
Offices	65	60	65	60	65	60
Engine control room (damage control room)			70	65	70	65
Gymnasium (hobby)	70	65	75	70	75	70
Chart room	60	55	60	55	60	55
Cargo control room (on a tanker)	60	55	65	60	65	60
Food preparation (galley, scullery, butcher, shop, thaw room)	70	65	75	70	70	65
Pantries	70	65	75	70	70	65
Storerooms	70	65	75	70	75	70
Laundries	70	65	75	70	75	65
Continuously manned machinery spaces (engine and auxiliary machinery rooms permanently occupied by personnel, control station in the room)	70	65	80	75	80	75
Not continuously manned machinery spaces (engine and auxiliary machinery rooms temporarily occupied by personnel for inspection purpose, control stations outside the room)	110	105	110	105		
Workshops	80	75	80	75	80	75
Electronic workshops	70	65	70	65	70	65
Cargo handling spaces/areas near cargo handling equipment	80	75				
Mess rooms	55	50	65	60	65	60
Ammunition room	75	70	80	75	80	75
Fire control room, Combat info centre + rooms belonging to CIC and occupied by personnel, sonar control room, electronic counter measure room	60	55	60	55	60	55
Spaces for equipment associated with communication, navigation and detection (not permanently occupied by personnel)	-	-	70	65	70	65
Bridge wings, out door	-	-	70	65	70	65
Weather deck stations permanently occupied by personnel	-	-	75	70	75	70

* Noise Rating Curves (NRC) as defined and specified in STANAG 4293



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Vår dato

2012-04-19

Vår referanse

2012/007339-002/FORSVARET/ 651

Tidligere dato

Tidligere referanse

Til

Forsvarets sanitet
Forsvarsstaben
Kysteskadren
Kystvakten
MJK
SSK
Sjø baser

Kopi til

Forsvarets mediesenter
Forsvarets operative hovedkvarter

Risikobasert støyovervåkning i Sjøforsvaret

1 Bakgrunn

Gjennom kartleggingsundersøkelser i Sjøforsvaret de siste årene er det påvist støynivå på Sjøforsvarets fartøyer som ligger over gjeldene tiltaksgrenser og grenseverdier i Forskrift for arbeidsmiljø, sikkerhet og helse for arbeidstakere på skip (FASH) og over anbefalte nivå i Forsvarets Navy rules and regulations (NRAR).

Undersøkelser gjennom prosjekt HMS SJØ gir indikasjon på øket forekomst av larmskader hos Sjøforsvarets personell.

Sjøforsvaret har som følge av dette iverksatt et støyprogram i form av arbeidsmiljøkartlegging og helseovervåkning i tråd med FASH.

2 Drøfting

Støyprogrammet består i hovedsak av to deler:

1. Måling av støy

Det gjennomføres en kartleggingsundersøkelse av samtlige fartøyer i Sjøforsvaret i tråd med retningslinjer gitt i NRAR. Metoden er verifisert av SINTEF og det praktiske arbeidet utføres av Universitetet i Bergen. Undersøkelsene skal gi Sjøforsvaret en bedret oversikt over status og gi grunnlag for tiltak i det videre arbeidet for å redusere risiko for larmskade og andre negative helse og arbeidsmiljøeffekter.

2. Helseovervåkning og helseundersøkelse

I tråd med FASH § 15-15 litra 1-3 gjennomføres det helseundersøkelse av personell i sjøtjeneste. Undersøkelsene omfatter i første rekke hørselskontroll og gjennomføres av bedriftshelsetjenesten i Sjøforsvaret og Saniteten ved Kystvakten.

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Vedlegg
0

Utvalgt personell vil også få vurdert andre helse og arbeidsmiljøeffekter av støy samtidig med målingen av områdestøy. Metoden for hørselskontroll er utarbeidet av Høresentralen ved Haukeland Universitetssykehus. Helsedata lagres i Sandok BHT journal.

Sjøforsvaret har ikke intern kapasitet eller kompetanse til å gjennomføre støyprogrammet. Det er derfor etter anbudskonkurranse inngått avtale med Universitetet i Bergen, med SINTEF og Norsk senter for maritim medisin som underleverandører.

Et viktig moment ved å involvere UiB er å bruke støyprogrammet til å vurdere gjeldene forskrift. Forskriften har begrunnede svakheter og programmet kan gi innspill til en eventuell revisjon av § 15, Bestemmelser om vern mot støy. Kunnskapsgrunnlaget for å bedømme støy og helsekonsekvensene er begrenset og det er behov med vitenskaplig tilnærming til problemstillingen.

Deltagelse i programmet anses som obligatorisk gitt FASH § 15-15 litra 2 der det fremkommer at Arbeidsgiver skal sørge for at arbeidstaker som utsettes for støy over gitte grenseverdier skal gjennomgå helseundersøkelse som omfatter hørselsundersøkelse. Resultatene fra helseundersøkelsen vil ikke bli benyttet til skikethetsvurdering i forhold til Sjøtjeneste og vil ikke bli tilgjengelig for lege som gjennomfører skikethetsvurdering.

Programmet har en ramme på tre år.

3 Konklusjon

Sjøforsvaret har iverksatt et støyprogram over tre år for å kartlegge støy på Sjøforsvarets fartøyer og undersøke sjølgående personell i henhold til Forskrift om arbeidsmiljø, sikkerhet og helse for arbeidstakere på skip.

Lars Johan Fleisje
Flaggkommandør
SSO STAB



Forespørsel om deltakelse i forskningsprosjektet

”Støy og helse i marinen”

Bakgrunn og hensikt

Dette er et spørsmål til deg om å delta i en forskningsstudie som heter «Støy og helse i marinen». Mange ansatte i Sjøforsvaret i Norge utsettes for støy og rapporterer nedsatt hørsel. Sjøforsvaret i Norge har besluttet å arbeide for å redusere helseplager relatert til støy på marinens fartøyer. **Målet er å arbeide for et bedre arbeidsmiljø på fartøyene.** Universitetet i Bergen, Arbeids- og miljømedisin vil i den anledning utføre et forskningsoppdrag for Sjøforsvaret som omhandler støy og helse. Støy vil bli målt på alle Sjøforsvarets fartøyer og hørsel vil bli målt blant alle ansatte. Vi vil studere sammenhengen mellom støy og hørsel i forskjellige grupper av ansatte. Videre vil sammenhengen mellom støy og våkenhet/reaksjonstid bli undersøkt i et mindre utvalg av ansatte, da støy kan være en indirekte årsak til ulykker ved f.eks. å påvirke våkenheten. Hjerterytme, søvn og reaksjonstid vil også bli undersøkt, for å se om det er sammenheng mellom disse faktorene og støyeksponeringen.

Hva innebærer studien for deg?

Du vil få undersøkt hørselen din, og blir bedt om å svare på noen få spørsmål om din bakgrunn og tidligere arbeid og fritidssysler. Dette vil skje i 2012 og 2013, og du kalles inn til disse undersøkelsene av bedriftshelsetjenesten. Til forskjell fra i en vanlig helsekontroll, blir dine helsedata brukt i forskning, dersom du samtykker til dette. Noen av de ansatte vil utvelges tilfeldig til flere undersøkelser mens de er ute og seiler. En gruppe av de ansatte på skipene vil bli spurt om å bære en støymåler 1-2 dager mens de er om bord. Dette er en liten, lett boks som du skal henge på ytterklærne, og som måler lyd kontinuerlig. Andre om bord vil bli spurt om å være med på en måling av hjerterytme. Dette består i å gå med en pulsklokke 1-2 dager. Videre vil vi registrere når disse sover i den perioden de går med støymåler, og de vil også måtte ha på en aktigraf, en annen klokke som måler dette. I tillegg vil vi teste reaksjonstiden til deltagerne ved begynnelse og slutt av arbeidsskiftet. Det tar litt tid å være med på undersøkelsene, men vi vil legge til rette så godt som mulig slik at undersøkelsen ikke virker forstyrrende på arbeidet ditt. Testene gir ikke ubehag.

Hva skjer med informasjonen om deg?

Støymålingene vil bli samlet i en rapport som beskriver støynivå for det skipet du var på mens målingene ble utført. Rapporten vil bli brukt til å evaluere behov for støyreduserende tiltak på skipet. Dersom vi finner noe unormalt ved målingene av hørsel, hjerterytme, søvn og reaksjonstid, vil vi kontakte deg om dette og følge det opp. Resultatene fra hørselstestene blir lagret i din journal i bedriftshelsetjenesten. Både bedriftshelsetjenesten og vi forskere har taushetsplikt.

Vi ber om at du gir oss navn og personnummer på et spørreskjema. Dette er fordi vi må sikre oss at alle prøvesvar knyttes til din person, og at vi kan gi deg tilbakemelding dersom det er nødvendig. Resultatene fra testene vil bli lagret uten navn og nummer i en database. En kode knytter dine opplysninger og prøvesvar til ditt navn via en navneliste. Det er kun autorisert personell knyttet til prosjektet som har adgang til denne listen og som kan finne tilbake til deg. Navnelisten og dataene blir slettet i 2019. Skjema som har ditt navn på oppbevares nedlåst i prosjektperioden. Resultatene skal publiseres i en rapport til Sjøforsvaret og i fagtidsskrifter, men det vil ikke være mulig å identifisere deg i disse resultatene

Frivillig deltakelse

Det er frivillig å delta i **studien**. Du kan når som helst og uten å oppgi noen grunn trekke ditt samtykke til å delta i studien. Dette vil ikke få konsekvenser for din videre behandling. Dersom du ønsker å delta, undertegner du samtykkeerklæringen på siste side.

Bergen, 13.april 2012

Bente E. Moen
Professor/lege
Tlf. 55586112/90025541

Kaja Irgens-Hansen
Forsker/lege
Tlf. 55586107/99411084

SPØRRESKJEMA FOR HØRSELSTEST



SKRIV TYDELIG, BRUK BLOKKBOKSTAVER!

 Lp.nr1. Fødselsnummer:

2. Navn: _____

3. Adresse, privat: _____

4. Mobilnr.: _____

Bakgrunnsdata:

5. Stilling: _____

6. Navn på fartøy du er om bord på i dag: _____

7. Arbeidsoppgaver til sjøs i dag: _____

8. Antall år du har arbeidet i Sjøforsvaret: År: 9. Antall år du har arbeidet på fartøy i Sjøforsvaret: År: 10. Ca. antall år/måneder effektiv seilingstid i Sjøforsvaret totalt: År: Mnd.:

Arbeidssted og tjenesteområde:

11. Hvilke arbeidssted og tjenesteområder har du hatt i Sjøforsvaret?
Her ber vi deg om å skrive antall år du har vært tilknyttet arbeidsstedene og krysse av for hvilke tjenesteområder du har hatt. Ta med førstegangstjeneste hvis aktuelt.

Arbeidssted	Antall år	Tjenesteområde		
		Operativ	Teknisk	Forvaltning
Fregatt	<input type="text"/> <input type="text"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Oksøy og Altaklasse	<input type="text"/> <input type="text"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
KNM Tyr	<input type="text"/> <input type="text"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
MTB Hauk eller eldre klasser	<input type="text"/> <input type="text"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
MTB Skjold	<input type="text"/> <input type="text"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Ubåt Ulaklassen	<input type="text"/> <input type="text"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Kystvakt, Sjøforsvarets egne fartøy	<input type="text"/> <input type="text"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Kystvakt, innleide fartøy	<input type="text"/> <input type="text"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Stridsbåt-90 (S90N)	<input type="text"/> <input type="text"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Forsyningsfartøy (KNM Valkyrien m.m.)	<input type="text"/> <input type="text"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
KS Norge	<input type="text"/> <input type="text"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Havnefartøy	<input type="text"/> <input type="text"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Minedykkerropp	<input type="text"/> <input type="text"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Kystjegerkommando felt	<input type="text"/> <input type="text"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Annet	<input type="text"/> <input type="text"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

12. Er du for tiden utsatt for så sterk støy i ditt arbeid at det er vanskelig å føre en samtale?

- Nei, aldri
- Mindre enn 5 timer i uken
- 5-15 timer i uken
- Mer enn 15 timer i uken

13. Har du vært utsatt for så sterk støy ved evt. tidligere arbeid at det var vanskelig å føre en samtale?

	I Sjøforsvaret	Utenfor Sjøforsvaret
Nei, aldri	<input type="checkbox"/>	<input type="checkbox"/>
Mindre enn 5 timer i uken	<input type="checkbox"/>	<input type="checkbox"/>
5-15 timer i uken	<input type="checkbox"/>	<input type="checkbox"/>
Mer enn 15 timer i uken	<input type="checkbox"/>	<input type="checkbox"/>
Nei, har ikke hatt annet arbeid tidligere	<input type="checkbox"/>	<input type="checkbox"/>

14. Har du vært utsatt for impulsstøy (smell/eksplosjoner e.l.) i arbeidet i Sjøforsvaret uten at du har brukt hørselsvern?

Ja Hvis ja, ca. hvor mange ganger:
Nei

15. Har du brukt/bruker du hørselsvern i støybelastede områder på fartøy i Sjøforsvaret i disse periodene?

	2010-2012	2000-2009	Før 2000
Ja, oftest	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Av og til	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Nei	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Ikke aktuelt	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

16. Hvor ofte har du arbeid der du bruker organiske løsemidler (maling/vasking med tynner)?

Daglig Ukentlig Månedlig Sjelden/aldri

Hvis du har eller har hatt slikt arbeid, hva slags arbeid er/var dette?

Hvis du har eller har hatt slikt arbeid, hvor mange år (ca.) har du jobbet med dette?

Antall år:

Dykking:

17. Har du drevet med dykking? (Kryss av en eller flere)

Ja, yrkesdykking i Sjøforsvaret
Ja, yrkesdykking utenfor Sjøforsvaret
Ja, fritidsdykking
Nei, aldri

18. Har du hatt øreskade etter dykking, (evnt. blitt behandlet i trykktank for øreskaden)?

Ja
Nei

Tidligere sykdom:

19. Har du noen av disse sykdommene?

	Ja	Nei
Hjertesykdom	<input type="checkbox"/>	<input type="checkbox"/>
Høyt blodtrykk	<input type="checkbox"/>	<input type="checkbox"/>
Sukkersyke (type 2)	<input type="checkbox"/>	<input type="checkbox"/>

20. Hadde du ørebetennelser som barn (0-17 år)?

Ja
Nei
Vet ikke

Hvis ja,

Ca. antall ganger: Vet ikke

Behandling (kryss av en eller flere):

Antibiotika
Dren
Ingen behandling
Vet ikke

21. Har du hatt ørebetennelser som voksen (fra 18 år)?

Ja
Nei
Vet ikke

Hvis ja,

Ca. antall ganger: Vet ikke

Behandling (kryss av en eller flere):

Antibiotika
Dren
Ingen behandling
Vet ikke

22. Er du plaget av tinnitus (øresus)?

Ja
Nei

Hvis ja, angi hvor sterke plager du har av tinnitus

Litt plaget Sterkt plaget

Ca. antall år:

23. Har du hatt annen øresykdom?

Ja
Nei

Hvis ja, hvilken: _____ Årstall for diagnose:

24. Har du hatt midlertidig nedsatt hørsel, dotter eller susing i ørene etter å ha vært utsatt for støy siste år?

Ja
Nei

Hvis ja, angi ca. antall ganger:

25. Er du plaget med svimmelhet?

Ja
Nei

26. Har du vært innlagt på sykehus på grunn av hodeskader?

Ja
Nei

Hvis ja, type skade: _____ Årstall:

27. Har, eller hadde noen i din nære familie nedsatt hørsel?

Mor Far Barn Søsknen Ingen nære

Medikamentbruk:

28. Har du benyttet ørefarlige medisiner tidligere (som for eksempel vanndrivende, bredspektret antibiotika, cellegift)?

Ja
Nei
Vet ikke

Hvis ja, hvilke(n): _____

Tobakk:

29. Bruker du/har du brukt tobakk?

	Røyk	Snus
Ja, daglig	<input type="checkbox"/>	<input type="checkbox"/>
Av og til	<input type="checkbox"/>	<input type="checkbox"/>
Tidligere	<input type="checkbox"/>	<input type="checkbox"/>
Nei	<input type="checkbox"/>	<input type="checkbox"/>

Støy på fritiden:

30. Har du drevet/driver du jakt?

Ja
Nei

Hvis ja,

Antall sesonger: Småvilt Storvilt

Bruker du hørselvern?

Ja, oftest Av og til Nei

31. Hvor mye har du drevet med skyting (inkludert i det militære + jakt + sport)?

Antall skudd siste år:

Oppgi type våpen: _____

Bruker du hørselvern?

Ja, oftest Av og til Nei

32. Har du spilt/spiller i musikk-korps eller band?

Ja Hvis ja, antall år:
Nei

33. Hvor ofte går du på konserter/utesteder e.l. hvor det spilles høy musikk?

Ukentlig Noen ganger pr. måned Noen ganger pr. år Sjelden/aldri

34. Bruker du mp3-spiller e.l. med hodetelefon/ørepluggen nå for tiden?

Mer enn 6 timer i uken 3-6 timer i uken 1-2 timer i uken Sjelden/aldri

35. Har du blitt øreskylt på fartøyet i forkant av denne hørselstesten?

Ja
Nei

TAKK FOR DELTAGELSEN!

Samtykke til deltakelse i studien

Jeg har lest informasjon om prosjektet, og er villig til å delta i studien

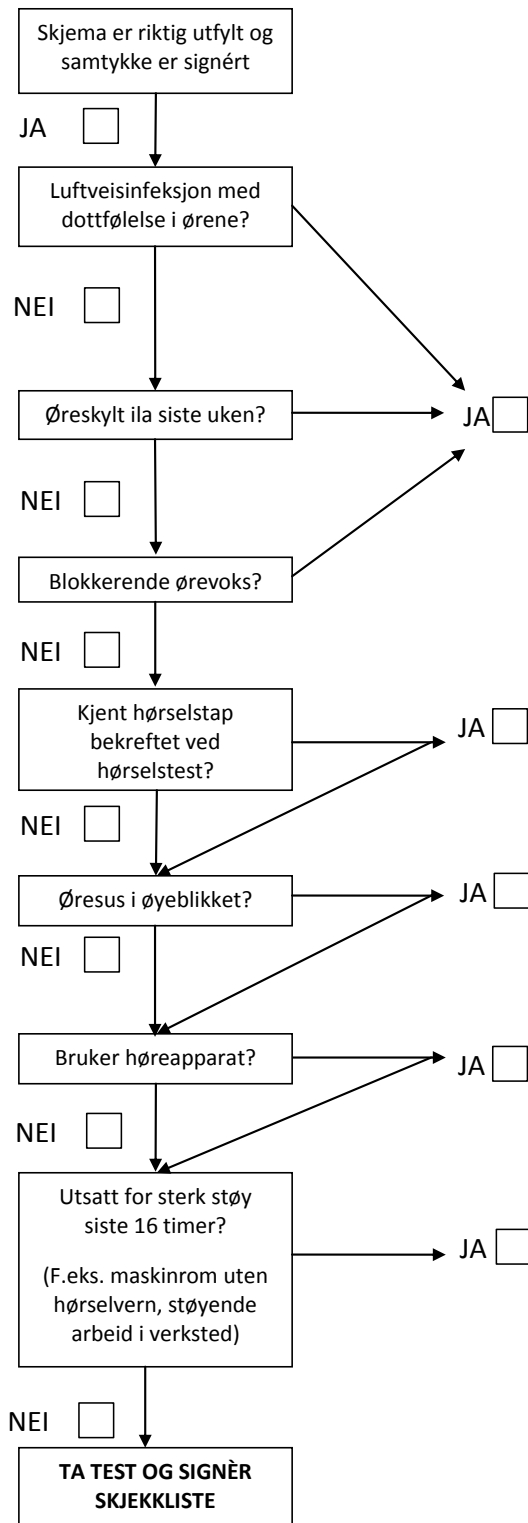
«***Støy og helse i marinen***»

Jeg gir tillatelse til at mine helsedata brukes i forskning.

Vennligst skriv navnet ditt med **blokkbokstaver** her:

Dato _____ Underskrift: _____

SJEKKLISTE – TIL SYKEPLEIER
FYLLES UT FULLSTENDIG OG SIGNERES FØR HØRSELSTEST



Ansvarlig sykepleier:

Dato/sted:

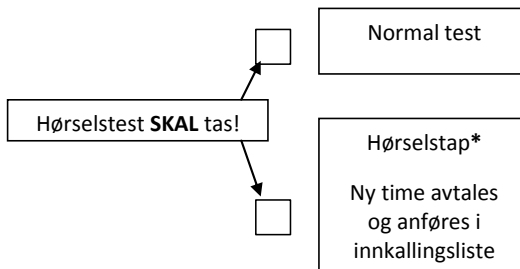
STOPP! Hørselstest skal IKKE tas!
 Ny time avtales og anføres i innkallingsliste

Type hørselstap: _____

Årstall for diagnose: _____

Ta manuell hørselstest med pulserende tone

Ta av høreapparat før test



* Hørselstap: ≥ 25 dB ved 3, 4 eller 6 kHz eller
 20dB for alle 3 frekvenser

SPØRRESKJEMA FOR HØRSELSTEST – SKJEMA 2



Skriv tydelig, bruk BLOKKBOKSTAVER!

 Lp.nr
1. Fødselsnummer:

2. Navn: _____

3. Adresse, postnummer, sted: _____

4. Mobilnr.: _____

Arbeidssted og tjenesteområde:

5. Navn på fartøy du er ombord på i dag: _____

6. Stilling: _____

Hovedarbeidsoppgave ombord:
 (kryss kun av én)

Dekksarbeid	<input type="checkbox"/>	Navigatør	<input type="checkbox"/>
Elektriker	<input type="checkbox"/>	OPS-rom	<input type="checkbox"/>
Kokk	<input type="checkbox"/>	Kontorarbeid	<input type="checkbox"/>
Maskinist	<input type="checkbox"/>	Våpenteknisk arbeid	<input type="checkbox"/>

7. Tilleggsarbeidsoppgaver ombord: _____

8. Effektiv seilingstid **siste 12 måneder:**

Eksempel: Tilknyttet KNM Roald Amundsen i 12 måneder, vært på sjøen ca. halve tiden. Seilingstid = 6 måneder.

9. Er du for tiden utsatt for så sterk støy i ditt arbeid ombord at det er vanskelig å føre en samtale?

- Nei, aldri
Mindre enn 5 timer i uken
5-15 timer i uken
Mer enn 15 timer i uken

10. Har du brukt hørselsvern i støybelastede områder på fartøy i Sjøforsvaret **siste 12 måneder**

- Ja, oftest
Av og til
Nei
Ikke aktuelt

11. Har du vært utsatt for impulsstøy (smell/eksplosjoner e.l.) i arbeidet i Sjøforsvaret uten at du har brukt hørselsvern **siste 12 måneder**?

- Ja Hvis ja, ca. hvor mange ganger:
Nei

12. Har du vært utsatt for impulsstøy (smell/eksplosjoner e.l.) utenfor Sjøforsvaret uten at du har brukt hørselsvern **siste 12 måneder**?

- Ja Hvis ja, ca. hvor mange ganger:
Nei

13. Hvor mye har du drevet med skyting (inkludert i det militære + jakt + sport)?

Antall skudd **siste 12 måneder**:

Oppgi type våpen: _____

Bruker du hørselsvern?

- Ja, oftest Av og til Nei

Hvilken hånd trekker du av med når du skyter med gevær?

- Venstre Høyre

14. Hvor ofte har du hatt arbeid der du bruker organiske løsemidler (maling/vasking med tynner) **siste 12 måneder**?

- Daglig Ukentlig Månedlig Sjelden/aldri

Hvis du har eller har hatt slikt arbeid **siste 12 måneder**, hva slags arbeid er/var dette?

Dykking:

15. Har du drevet med dykking **siste 12 måneder**? (Kryss av én eller flere)

- | | |
|---------------------------------------|--------------------------|
| Ja, yrkesdykking i Sjøforsvaret | <input type="checkbox"/> |
| Ja, yrkesdykking utenfor Sjøforsvaret | <input type="checkbox"/> |
| Ja, fritidsdykking | <input type="checkbox"/> |
| Nei | <input type="checkbox"/> |

16. Har du hatt øreskade etter dykking **siste 12 måneder**, (evt. blitt behandlet i trykktank for øreskaden)?

- | | |
|-----|--------------------------|
| Ja | <input type="checkbox"/> |
| Nei | <input type="checkbox"/> |

Tidligere sykdom:

17. Har du fått påvist noen av disse sykdommene **siste 12 måneder**?

- | | Ja | Nei |
|---------------------|--------------------------|--------------------------|
| Hjertesykdom | <input type="checkbox"/> | <input type="checkbox"/> |
| Høyt blodtrykk | <input type="checkbox"/> | <input type="checkbox"/> |
| Sukkersyke (type 2) | <input type="checkbox"/> | <input type="checkbox"/> |

18. Har du hatt ørebetennelser **siste 12 måneder**?

- | | |
|----------|--------------------------|
| Ja | <input type="checkbox"/> |
| Nei | <input type="checkbox"/> |
| Vet ikke | <input type="checkbox"/> |

Hvis ja,

Ca. antall ganger: Vet ikke

Behandling (kryss av én eller flere):

- | | |
|------------------|--------------------------|
| Antibiotika | <input type="checkbox"/> |
| Dren | <input type="checkbox"/> |
| Ingen behandling | <input type="checkbox"/> |
| Vet ikke | <input type="checkbox"/> |

19. Har du vært plaget av tinnitus (øresus) **siste 12 måneder**?

- | | |
|-----|--------------------------|
| Ja | <input type="checkbox"/> |
| Nei | <input type="checkbox"/> |

Hvis ja, angi hvor sterke plager du har av tinnitus

- | | | | |
|-------------|--------------------------|---------------|--------------------------|
| Litt plaget | <input type="checkbox"/> | Sterkt plaget | <input type="checkbox"/> |
|-------------|--------------------------|---------------|--------------------------|

20. Har du fått påvist annen øresykdom **siste 12 måneder**?

- | | |
|-----|--------------------------|
| Ja | <input type="checkbox"/> |
| Nei | <input type="checkbox"/> |

Hvis ja, hvilken: _____

21. Har du hatt midlertidig nedsatt hørsel, dotter eller susing i ørene etter å ha vært utsatt for støy **siste 12 måneder**?

I Sjøforsvaret:

Ja Hvis ja, angi ca. antall ganger:
Nei

Utenfor Sjøforsvaret:

Ja Hvis ja, angi ca. antall ganger:
Nei

22. Har du vært plaget med svimmelhet **siste 12 måneder**?

Ja
Nei

23. Har du vært innlagt på sykehus på grunn av hodeskader **siste 12 måneder**?

Ja
Nei

Hvis ja, type skade: _____

Medikamentbruk:

24. Har du benyttet ørefarlige medisiner **siste 12 måneder** (som for eksempel vanndrivende, bredspektrert antibiotika, cellegift)?

Ja
Nei
Vet ikke

Hvis ja, hvilke(n): _____

Tobakk:

25. Har du røykt **siste 12 måneder**?

Ja, daglig
Av og til
Tidligere
Nei

26. Har du snust **siste 12 måneder**?

Ja, daglig
Av og til
Tidligere
Nei

Støy på fritiden:

27. Har du gått på jakt **siste 12 måneder**?

Ja
Nei

Hvis ja,

Småvilt Storvilt

Bruker du hørselvern på jakt?

Ja, oftest Av og til Nei

28. Har du spilt i musikk-korps eller band **siste 12 måneder**?

Ja
Nei

29. Hvor ofte har du gått på konserter/utesteder e.l. hvor det spilles høy musikk **siste 12 måneder**?

Ukentlig Noen ganger pr. måned Noen ganger pr. år Sjelden/aldri

30. Bruker du mp3-spiller e.l. med hodetelefon/øreplugger nå for tiden?

Mer enn 6 timer i uken 3-6 timer i uken 1-2 timer i uken Sjelden/aldri

31. I deler av barndommen, var du ofte i nærheten (på noen få meter hold) når det ble fyrt av kinaputter eller andre kraftige smellsaker?

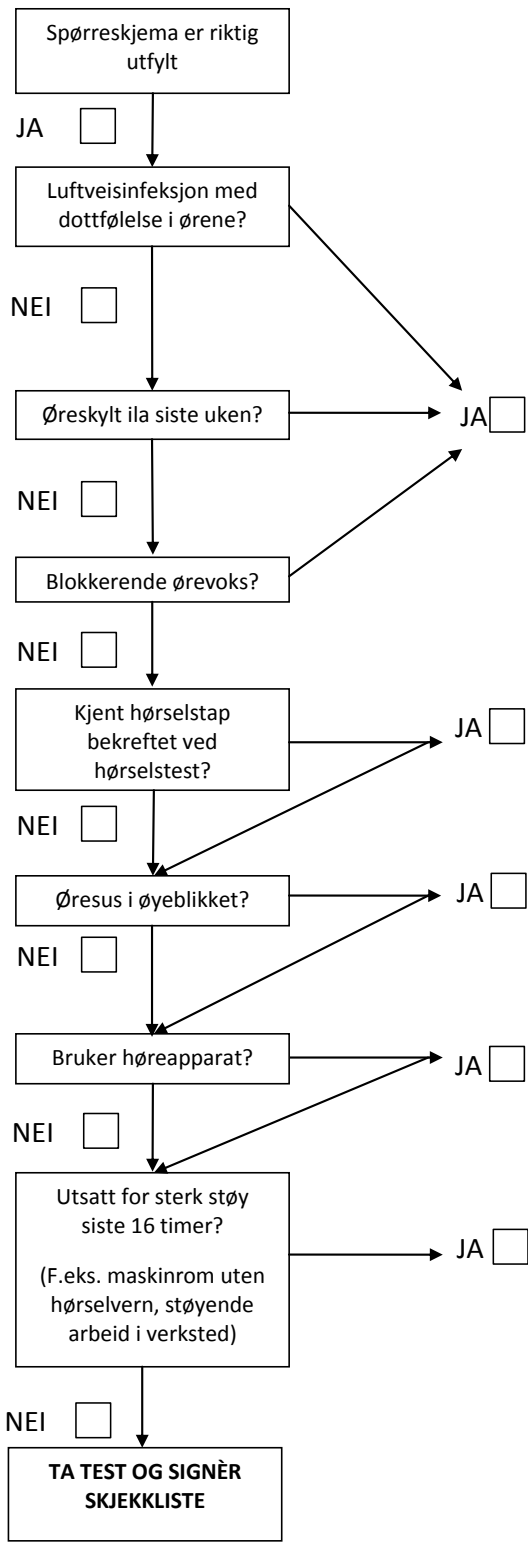
Ja, flere ganger i året
Sjelden
Aldri

32. Tror du at du har fått hørselstap **siste 12 måneder**?

Ja
Nei
Vet ikke

TAKK FOR DELTAGELSEN!

SJEKKLISTE – TIL SYKEPLEIER
FYLLES UT FULLSTENDIG OG SIGNERES FØR HØRSELSTEST



Ansvarlig sykepleier:

Dato/sted:

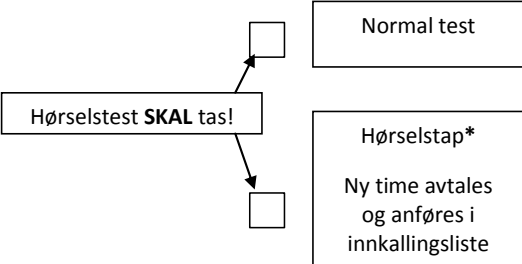
STOPP! Hørselstest skal IKKE tas!
 Ny time avtales og anføres i innkallingsliste

Type hørselstap: _____

Årstall for diagnose: _____

Ta manuell hørselstest med pulserende tone

Ta av høreapparat før test



* Hørselstap: ≥ 25 dB ved 3, 4 eller 6 kHz eller 20dB for alle 3 frekvenser

V

RUTINER FOR HENVISNING TIL HØRESENTRAL/MR

Asymmetri

Tinnitus

Ensidig

Hørseltap

≥ 20 dB ved en frekvens

≥ 15 dB ved to frekvenser

NB! Bekreftet ved to separate målinger

Disse kan egentlig henvises til MR direkte og det kan gjøres av BHT

Diagnostikk

Hørseltap med usikker/ukjent diagnose, spesielt usikker støydiagnose.

Hørsel

Pasient som ønsker å prøve høreapparat.

(umulig å forutsi ut i fra audiogrammet, men med hørseltap < 40 dB for 4/6 kHz og ≤ 20 dB for 2 kHz er det sjelden stor nytteverdi av HA.)

Tinnitus

Pasient som trenger hjelp til å mestre tinnitus

Mars 2012.

Prosjekt: Støy og helse i marinen
PROSEDYRE VED AUDIOMETRI – 2013



Hvem skal undersøkes?

- Alle ansatte i Sjøforsvaret som arbeider på Sjøforsvarets fartøyer (også sivile) NB! De som er inne til førstegangstjeneste skal ikke undersøkes.
- Alle de ansatte (sett bort fra sivile) er pliktige til å gjennomføre audiometri men den ansatte kan velge å ikke samtykke til deltakelse i studien. Informasjon om plikt skal henge på venteværelse.

Tidspunkt for undersøkelse

- Audiometri gjennomføres selv ved eksponering for spesielt støvende arbeid siste 16 timer. Hvis test viser hørselsreduksjon (se «oppfølging») må ny test tas neste mulige dag. Anføres i sjekkliste, ny dato føres i innkallingsliste.
- Undersøkelsen skal **ikke** utføres dersom man har pågående luftveisinfeksjon (spør om tette bihuler/nese og dottfølelse) da dette kan gi midlertidig redusert hørsel. Anfør eventuell luftveisinfeksjon i sjekkliste. Undersøkelsen gjentas når man har blitt frisk. Ny dato føres i innkallingsliste.
- Fysisk anstrengelse like før undersøkelsen kan gi feil på måleresultatet. Den som undersøkes må derfor ha vært i ro 5 minutter før undersøkelsen.

Spørreskjema/Informasjonsskriv/Samtykke

- De som har deltatt i første runde av hørselstesting skal fylle ut spørreskjema 2 og behøver ikke å samtykke på nytt. Nye ansatte eller ansatte som ikke deltok i første runde skal motta informasjonsskriv, fylle ut spørreskjema 1 og samtykkeskjema dersom de ønsker å delta i studien. Samtykkeskjema er vedheftet spørreskjema 1.
- Den som foretar audiometrien må være tilgjengelig for spørsmål og skal gå gjennom spørreskjema for å se at alt er fylt ut korrekt og signere sjekkliste (navn, dato og sted).
- Audiometriresultatene skal lagres i Sandok BHT. Informasjonen her kan ikke kobles opp mot andre systemer, f.eks. knyttet til sertifiseringer o.l. Sortland: Spørreskjema/samtykke/sjekkliste fraktes til HOS av Christin Pedersen. Innkallingslister sendes til kaja.irgens@igs.uib.no.

Otoskopi

- Før audiometri **skal** ørene undersøkes ved otoskopi for å finne ut om ørevoks blokkerer øregangene. Blokkerende ørevoks skal fjernes og audiometri skal utsettes minst en uke. Dersom de ansatte er sjekket på fartøyet spør om de ble øreskylt og tidspunkt for dette.
- Før øreskylling må man spørre om tidligere øreproblemer, som f.eks. hull på trommehinnen, kronisk ørebetennelse og øreoperasjon. I slike tilfeller bør BHT henvise til øre-nese-hals-spesialist eller høreentral for å få fjernet ørevoksen.
- Dersom det er vanskelig å fjerne voksen: La den som undersøkes ligge på benk med lunkent vann i øret i 20 min slik at voksen får løst seg opp. Dette er ofte mer effektivt enn olje som fungerer best på stive skorper.

Plassering/Instruksjon/Audiometri

- Audiometeret Interacoustics AD226 skal benyttes med Peltor øreklokker, utstyret skal varmes opp i minst 5 minutter.
- Personer med tinnitus har ofte vansker med å skille mellom sin egen øresus og testtonene. Manuell testing med pulstone skal benyttes. Tinnitus anføres på sjekklisten.
- Dersom en bruker høreapparat skal dette tas ut under hørselstest. Bruk av høreapparat skal anføres i sjekkliste. Manuell testing skal benyttes ved kjent redusert hørsel.
- Ta av ytterjakke, slå av lyd på mobiltelefon og legg på venteværelse. Ta av briller, hodeplagg, ørepynt, høreapparat og skyv bort hår som kommer mellom.

Juster hodebøylens lengde til ytterste posisjon. Den ene hodetelefonen holdes på plass, mens den andre justeres. Til slutt senkes hodebøylene mens hodetelefonene presses mot ørene. Senteret på hodetelefonen må komme rett over øregangen. Spør om den sitter greit. Den som undersøkes skal få beskjed om ikke å røre hodetelefonen etter den er satt på plass. RØD = HØYRE, BLÅ = VENSTRE.

Instruksjonsguide skal henge på vegg i audiometriboks.

- Den som skal undersøkes må ikke kunne se bevegelsene til den som utfører målingen.
- Den som undersøkes må få nøyaktig beskjed om hva som skal foregå og instruksjonen må være oppfattet før man starter (se eget forslag til instruksjon).
- Testpersonen bør sitte i ro i minst 30 sek før undersøkelsen starter.
- Automatisk audiometri skal benyttes. Ved usikkerhet omkring høreterskler og ved øresus skal manuell metode vurderes.

Manuell testing:

Teste alle frekvenser på høyre øre, deretter på venstre øre (omvendt hvis venstre øre har best hørsel)

- Rekkefølge: 1000 Hz - 2000 Hz – 3000 Hz - 4000 Hz - 6000 Hz - 8000 Hz - 500 Hz - 250 Hz - 1000 Hz
- Starte med 40 dB for normalthørende
- 10 dB ned, 5 dB opp, varighet på 1-2 sekunder, unngå rytme!
- Bekreftet høreterskel når 2 like svar

Oppfølging

- Ny test grunnet **støyeksponering** gjennomføres hvis:
Hørselstapet for en eller flere av frekvensene 3000, 4000 og 6000 Hz er fra og med 25 dB eller hørselstap på minst 20 dB for alle tre frekvensene.
- Utskrift av audiometriresultat, spørreskjema/sjekkliste og samtykke skal oppbevares nedlåst i mapper.
- Prosjektleder er ansvarlig for oppfølging av avvikende resultat og eventuelle henvisninger i samarbeid med bedriftshelsetjenesten.

HUSK Å HA EKSTRA BATTERI/LAMPE TIL OTOSKOP, RIKELIG MED ØRETUBER OG EKSTRA TONER TIL SKRIVER TILGJENGELIG TIL ENHVER TID! TEST AUDIOMETRIAPPARATET HVER UKE!



Prosjekt: Støy og helse i marinen

KONTROLLRUTINER

HVER DAG

- Utstyret skal varmes opp i minst 5 minutter
- Sjekk støpsler og ledninger med tanke på brudd og at brytere, lamper og indikatorer fungerer riktig

HVER UKE

- Rengjør og kontroller audiometeret og alt tilbehør (hodetelefonputer, ledninger m.m.) med tanke på skade/slitasje.
- Sjekk alle frekvenser i begge hodetelefoner i hele styrkeområdet (Ca. 10-15 - 60 dB). Det skal ikke være forvrengninger, avbrudd, klikkelyder osv.
- Sjekk at signaliseringssystem fungerer som det skal.
- Sjekk spennkraften i hodebøylen og at dreieledd er fritt bevegelig uten å være for slakke, slik at hodetelefonen sitter ordentlig. Se etter tegn på slitasje og materialtretthet.

HVERT ÅR

- Kalibrering skal utføres av kompetent laboratorium
- OBS: Hodetelefon skal være den samme som utstyret er kalibrert med

HUSK Å HA EKSTRA BATTERI/LAMPE TIL OTOSKOP, RIKELIG MED ØRETUBER OG EKSTRA TONER TIL SKRIVER TILGJENGELIG TIL ENHVER TID!



Prosjekt: Støy og helse i marinen

INSTRUKSJON

FØR TEST

- Legg fra deg ytterjakke utenfor boksen.
- Slå av lyd og legg mobiltelefon utenfor boksen.
- Ta av følgende:
 - Brilller
 - Hodeplagg
 - Ørepynt
 - Høreapparat
 - Skyv bort hår som kommer mellom

TILPASSING AV HODETELEFON

Juster hodebøylens lengde til ytterste posisjon.

RØD - HØYRE SIDE

BLÅ - VENSTRE SIDE

Den ene hodetelefonen holdes på plass, mens den andre justeres.

Hodebøylen senkes mens hodetelefonene presses mot ørene. Senteret på hodetelefonen må komme rett over øregangen. Du må ikke røre hodetelefonen etter den er satt på plass.

HØRSELSTEST

Du må sitte i ro i minst 30 sek før undersøkelsen starter.

Gi beskjed hvis du har noen spørsmål eller hvis hodetelefonen ikke sitter som den skal.

- Høyre øre testes først, deretter venstre.
- Når du hører en tone trykker du på knappen, hold inne knappen så lenge du hører tonen og slipp knappen når tonen blir borte.
- Selv om tonen er så svak at den bare så vidt kan høres skal du angi at du hører den. Ikke trykk hvis du er i tvil.
- Sitt stille og avslappet, alle bevegelser, kremting o.l. forstyrrer målingene.

Instruksjon til den som skal undersøkes

Det er viktig at den som skal undersøkes får nøyaktig beskjed om hva som skal foregå og at instruksjonen blir oppfattet. Instruksjonen kan f.eks. være slik:

«Vi skal nå undersøke hørselen ved at du får høre forskjellige pipetoner i hodetelefonen. Vi prøver ett øre om gangen og begynner med høyre øre. Vi begynner med en middels lys tone, og etter hvert blir tonene enda lysere. Deretter får du høre en mørkere tone og til slutt en middels lys tone. Deretter tester vi det venstre øret på samme måte. Når du hører en tone, gir du signal ved å rekke opp en finger (eller trykke på en knapp). Prøv å «følge» lyden slik at fingeren rekkes opp (knappen trykkes inn) straks du hører tonen, at du holder fingeren oppe (knappen inne) så lenge tonen høres og at du tar ned fingeren (slipper knappen) med en gang tonen blir borte. Selv om tonen er så svak at den bare så vidt kan anes, skal du angi at du hører den. Er du i tvil, gir du ikke noe tegn. Sitt ganske stille og avslappet, for alle bevegelser, kremting og lignende, forstyrrer målingene. Dersom du blir forstyrret av en eller annen grunn og ønsker å avbryte undersøkelsen, gir du bare beskjed om dette. Har du forstått hva vi skal gjøre?»

Støyprosjekt i Sjøforsvaret

Loggbok for registrering av aktivitet under seiling og målinger

- Støymålinger
- Hjertevariabilitet
- Kognitiv testing og søvn

PersonNR.: _____

NAVN: _____

HØYDE/VEKT: _____

MEDIKAMENTBRUK: _____

DATO: _____

FARTØY: _____

STILLING: _____

Lugar nr: _____

SERIENR. PULSKLOKKE: _____

SERIENR. STØYMÅLER: _____

AKTIGRAF SRNR.: _____

MÅLESERIE: _____

KLOKKELETT START: _____

KLOKKELETT SLUTT: _____

SKJEMAKODE: _____

TID:	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	01	02	03	04	05	06	07	08		
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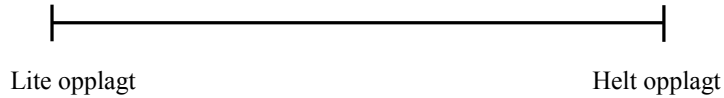
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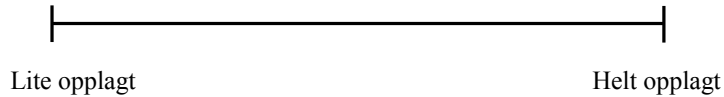
Hvor opplagt føler du deg akkurat nå?

Sett kryss på linjen.

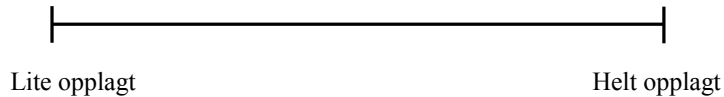
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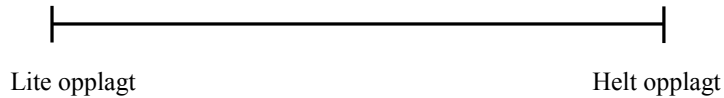
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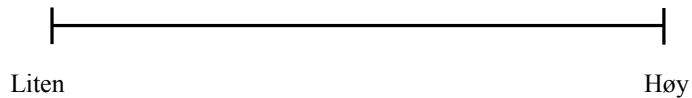
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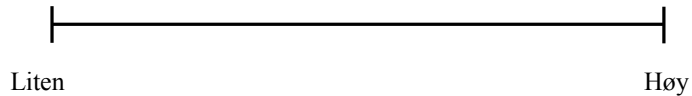
Hvordan var arbeidsbelastningen din siste vakt?

Sett kryss på linjen.

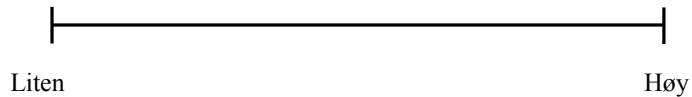
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