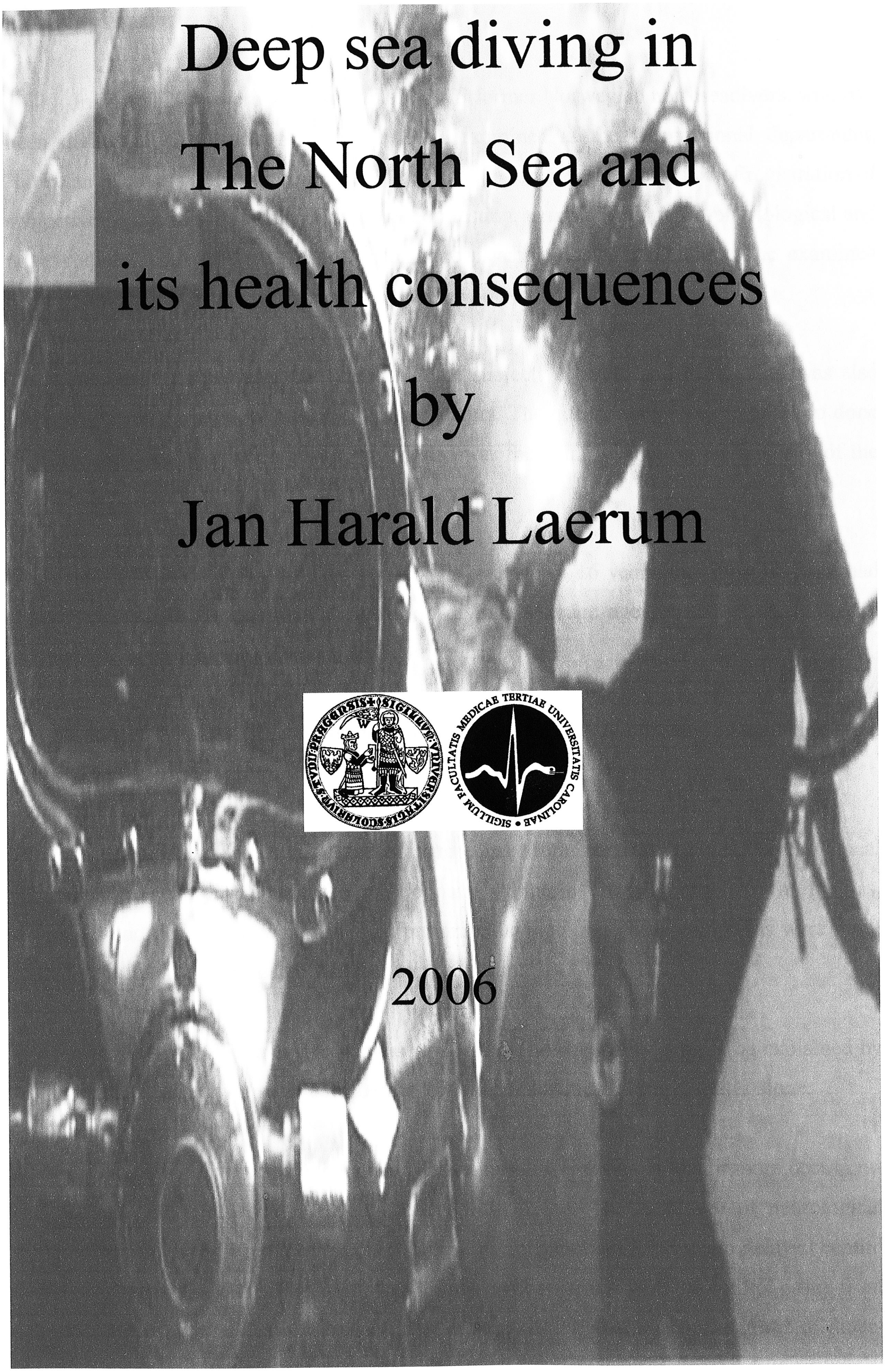

Deep sea diving in The North Sea and its health consequences

by

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Summary

In March 2004 were 96 from a total of 375 former Norwegian northseadivers, who had been diving in The North Sea before 1990, examined at the Occupational department, Haukeland University Hospital, Bergen. The examination program consisted of registration of subjective health and life quality, lung function testing, neurological, neuro-physiological and neuro-radiological examination, and also neuro-psychological examination. The examined divers had longer cumulative diving time than the non-examined.

The same questionnaire used for registration of subjective health and life quality was also given to the remaining pool of non-examined divers. The questionnaire was in addition done by a age matched population group, which also was the control group in the majority of the examinations.

The examined divers had a diving career for an average of 16 years, and most of them had experience with both bounce- and saturation diving. Average age was 52 years. It was in average 12 years since they finished their diving career.

The portion of divers which who received disability benefit at the time of examination were higher than the control group.

The examined divers reported a lot of symptoms from nervous system, psychological complains and pain problems in the questionnaire. Amnesia, attention problems, arthralgias, sleepiness and depression were the most prominent symptoms. These complains were more common in the divers compared with the control group.

The incidence of COPD among the divers was 5.1%. The occurrence cannot be explained by smoking habits, allergy/atopy predisposition or other occupational lung diseases alone.

80 of the examined divers had experienced decompression sickness in one or more occasions, and 34 had been unconscious in connection with diving. The incidence of neurological symptoms and findings, reduced speed of signalling in spinal cord, slow and delayed central response to stimuli, and EEG changes, were higher in comparison with the control group from the general population. The occurrence of these neurological findings in the group of divers

cannot be explained by other known factors as age, earlier head trauma, CVD, or alcohol habits.

The divers had spotty reduction in cerebral blood flow and brain volume compared to the controls, mostly seen in the left hemisphere.

Approximately 90% of the examined divers had in connection with diving been involved in serious episodes with danger of own or companion's life. Most of them had also been involved in search of deceased colleagues.

A majority of the divers showed psychological stress reactions, which only can be observed after sub sea level work. A considerable amount of the divers filled the criteria for PTSD diagnosis by clinical evaluation.
The findings in this investigation are compatible to the results from the epidemiological studies which were done by active divers in the late 80s, and in connection with the conclusions from the Godoeysund conference in 1993.

Introduction

Diving in The North Sea started with the extensions of the great oilfields in the 70s and the beginning of the 80s down to depths from 60 to 180 meters. Through the 80s there was done experimental diving to depths between 300 to 500 meters to enhance diving procedures in connection with development of oilfields situated in these depths. A research project was started by the Norwegian oil companies and NTNF(Norwegian Technical and Science Research Council) in connection with these experimental dives to investigate possible long-term side effects of this kind of diving. This work was mainly done between 1985 and 1990. The results indicated long-term effects on CNS and lung function, and there were big discussions concerning the clinical relevance of these results between scientific experts and the divers.

The Norwegian and the foreign studies available at that time were reviewed in the international consensus conference concerning long-term effects of diving in 1993 in Godoeysund(Norway). The conclusions were:

There are proved changes in the skeleton, CNS and lungs in divers who have not been involved in diving accidents or exposed to other occupational hazards.

These changes are in the majority of the cases small and have no influence on the divers quality of life.

The changes are at the same time by such a character that it may influence the future health of the divers.

From 1998 the Occupational Department, Haukeland University Hospital was receiving an increased amount of referrals of divers for further evaluation concerning changes which may be compatible with the results of the conclusions in the Godoeysund conference. It has been an increase interest in the media concerning the responsibility for this diving at the same time, not only the medical, but also the technical, procedural and psychosocial working conditions. This has been investigated by the national appointed "Investigating committee for the pioneer diver conditions in the North Sea".

In the report from the Ministry of Local Government committee concerning the health and safety of work related diving from 1993 it is noted that there is no continuous health service for the divers, which has the responsibility to start the necessary medical and disability measures when sign of health damage on the divers starts.

The Occupational Department, Haukeland University Hospital, got in 1998 a request from the National Board of Health to consider which types of health damage from diving which would yield disability benefit.

The report from the Occupational Department especially went through the scientific material which was published after the Godoeysund conference, and concluded that there was no new knowledge which sought doubt about the conclusions from that conference. The report concluded among other factors that "obstructive lung disease and encephalopathy may be a side effect to dive exposure, but in that case must be sure that other known causes are ruled out."

It was further concluded that occupational diving involve a risk for events that may result in PTSD. This problem has never been tried to be mapped among divers, and is not mentioned in scientific medical diving literature.

In June 1999 all National Health Insurance Offices were given a notification to refer all persons with a probable dive related disease to Haukeland University Hospital for evaluation. Haukeland University Hospital made in 2000 an examination protocol for divers referred with suspicion of dive related disease and injury. This examination includes divers who were working in the North Sea before 1990. It is the same diver population and era as the "Investigating committee" has examined.

The report of the "Investigating committee" was finished 31.12.03. It was done a thorough review concerning possible causes of long-term effects, and of studies - both Norwegian and foreign - which these facts are based on. The committee concluded that "we do not have sufficient data which can give us answers if normal diving may result in neurological/cognitive long-term effects", and "if correct executed deep sea diving may lead to long-term and permanent neurological/cognitive injuries." The committee underlined meanwhile the professional disagreement about this topic in different research groups.

The material concerning examinations of health impact of diving before 2004 was from divers who were working at the moment of examination. Earlier investigations may have underestimated the occurrence of health effects, because only divers who were able to work were selected. The investigation done at Haukeland University Hospital was done the other way round by the way that it was concerned about the divers who actually were sick. In the spring 2004 the report from the investigation in 1990 in Aberdeen concerning the British divers in the North Sea was released. There were comparable results from parts of the examination done in Aberdeen and Haukeland.

Exposure to diving

Diving is exposure to increased ambient pressure in relation to normal atmospheric pressure on the spot where the dive has its starting point. Diving is usually connected with activity in water, but operations under increased pressure may also take place in dry environment e.g. treatment of decompression sickness in pressure chamber, welding in dry habitats and working in tunnels. What kind of dive technique which is used is dependent on what type of work which should be done and the actual depth at the place where the work is done.

All dives are characterized by 3 phases. The compression phase is the time for pressurization to actual working depth. The bottom phase is the time when the diver stays at the actual working depth, and the decompression phase is the time from when the diver leaves the working depth until he reaches the surface.

Methods of diving

Free diving

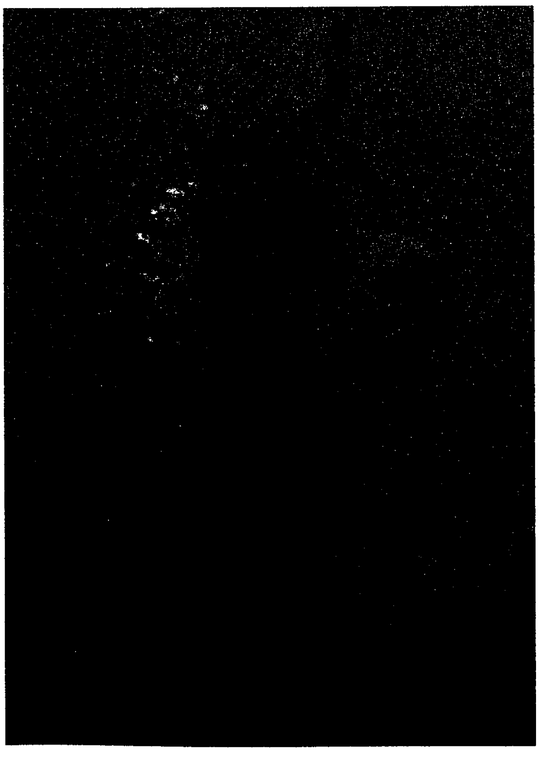
When free diving you do not carry a reserve of air and this limits the available time for work in sub sea level and the depth which is practically achievable. In commercial context free diving is still used for harvesting of sea food in regions of Japan and Korea, the so-called AMA divers. Free diving is a well-known leisure activity in tropical countries, as well as in the Scandinavian countries. Mask, flippers and wetsuit are usually used. When you are free diving you do not breath air in increased ambient pressure and therefore are the physiological and medical limits and problems different from other types of diving.

SCUBA diving

In this form of diving the diver brings a supply of breathing gas in a cylinder which usually is carried on the back. The abbreviation SCUBA is short for Self Contained Underwater Breathing Apparatus. In this form and the later mentioned forms of diving, gas under increased ambient pressure is breathed in. This has physiological and medical implications in the way that the gases are dissolved in body fluids and tissue until they are saturated with the given gas, and that the gas has to be liberated from the tissues under the decompression phase whit out excessive production of gas bubbles and tissue damage.

Air is normally used as breathing gas, but in special occasions other gas mixtures are used. Scuba diving is used seldom in occupational connections, but predominantly in sport diving.

Helmet and umbilical diving



In this type of diving the diver is supplied with breathing gas from a pump on the surface, and gives the diver a free access of gas in the diving helmet. Also in this type of diving the diver is breathing gas in an increased ambient pressure in relation to the depth of where the work is being done. The medical and physiological challenges are the same as with SCUBA diving. The equipment is heavier and is mainly suited for construction work under water, and gives limited mobility in relationship with usage of SCUBA equipment.

Helmet and umbilical diving belongs also under the entity surface-oriented diving. A surface-oriented dive is defined as a diving operation where the diver enters and leaves the water at normal ambient pressure. In surface-oriented diving there is a possibility to prolong the bottom time at a given depth by supplying the diver with a gas-mixture containing higher oxygen percentage than normal air. Normally used mixtures contain nitrogen and oxygen where the share of oxygen varies from 30 - 60%. The decompression time is determined by the amount of inert gas which is dissolved in the tissues. With usage of oxygen-rich gas you decrease the amount of dissolved inert gas, but the danger of oxygen toxicity is thus greater.

Oxygen diving

With usage of breathing-gas supply of pure oxygen and a device which absorbs carbon dioxide ("scrubber"), you can dive with a closed-circuit breathing apparatus. There is a depth limit of 7-10 meters, because of the toxic effects of oxygen. But there is no problems connected with decompression phase in such dives. This method is only used for military operations.

Tunnelling under increased ambient pressure – "Caisson work"

During tunnel driving in unfixed masses there is often necessary to inhibit entry of water at the working place by pressurization. The workers need to be pressurized and locked into the workplace. Pressurization is usually done with air. This is diving in dry environment.

Bounce diving

Air is not a suitable breathing gas when diving to depths deeper than 50 meters. Nitrogen has a narcotic effect at pressures corresponding to depths from 40 – 50 meters under the surface, and the effect increases with increased pressure. The density of air in those pressures increases the resistance to breathe greatly. For replacement of air other gas-mixtures are used with the content of oxygen adapted to the actual working depth and other inert gases than nitrogen. With special developed decompression procedures consisting of high partial pressure of oxygen and gas-exchange there is a possibility to achieve bottom time long enough to do complicated operations at depths between 50-100 meters.

In the early phase of the North Sea diving the "bounce"- diving was a common diving procedure until saturation diving overtook the throne in the late 70s.

Saturation diving

In this diving method of diving all body tissues are saturated with the gas which is used during the dive, usually a mixture of oxygen and helium. The decompression procedures need to be adjusted to the fact that all tissues in the body are saturated with inert gas, and that the length of the bottom time is not the determining factor for the decompression time. The divers are pressurized in a special pressure chamber complex on board a special constructed diving-ship to a pressure which corresponds to the working depth. They are moved from the pressure chamber complex to a diving bell which is transported to the working place, and the divers move from the bell and into the water. There are breathing gas supply, hot water supply for thermal protection, and intercom through pipes winded together to a so-called "umbilical". The pressure chamber complexes have capacity to pressurize 12-16 divers. That means that several teams may dive in the water on shifts. The divers stay in this pressure in the chambers up to 14 days, after which a slow decompression starts with a speed of 20-25 meters per day. Normal work depths in the North Sea are between 50-220 meters.

Physical exposure factors

All forms of diving are characterized by exposure to increased pressure in a given time with a given breathing gas. The exception is free diving where no breathing of gas with increased ambient pressure is done. In addition to these basal physical parameters to characterize the diving profile there are other physical characteristics concerning the ambient environment where the diving is done which also is of importance.

Factors which are associated with diving and which are known to have physiological and medical effects are all functions of the basal physical characteristics; pressure, time and gas mixture. It is therefore not qualitative, but quantitative differences between the different forms of diving.

Decompression stress

The amount of inert gas which is dissolved in the tissues is a function of pressure and time for compression and bottom phase. The increase in the amount of inert gas which is dissolved in the tissues follows an exponential function and different tissue has different time constants. Inert gas shall be released from the tissues by decompression and if some tissues are over-saturated in proportion to the ambient pressure, gas bubbles may develop. Development of gas bubbles may happen in the interstitial tissues or in the venous system where the over-saturation is greatest. The possibility of gas bubble formation in arterial blood *per se* is low, because the amount of gas in arterial blood is in close equilibrium with the gas pressures in the alveoli and with that the ambient gas. Gas bubble formation is a necessary prerequisite for the development of decompression sickness.

The decompression phase is characterized by pressure change per time unit. Decompression procedures which are used adjust the time of decompression according to dissolved inert gas in the tissues (depth and bottom time) in such a way that the risk for clinical decompression sickness is on an "acceptable level".

Bubbles formed *in situ* may result in local tissue damage. Bubbles formed in the venous circulation will filtrate into the respiratory circulation and reduce the gas-exchange function. Venous gas bubbles may pass the respiratory circulation in AV-shunts or pass through a patent foramen ovale into the systemic circulation. It is necessary to define precisely that bubbles are a result of decompression stress and not a diving exposure factor.

Oxygen toxicity

The toxic effects of oxygen are well-known. If exposed to partial pressure above 140 kPa acute neuro-toxic effects with generalized seizures may develop. At partial pressure of 50 kPa, and at long term exposure as in saturation diving, has oxygen at 30-40 kPa a toxic effect on the lungs. The oxygen exposure during a dive is given by the partial pressure of oxygen in the gas-mixture and the time.

Gas density

The internal breathing resistance is proportional to the gas density. The maximal respiratory velocity of flow and ventilation capacity is inverse proportional to the square-root of the gas density. The capacity of the ventilation becomes physically limited when air is used as breathing gas at pressures corresponding to depths between 20-30 meters. The gas density is depends upon the gas mixture and pressure. At great depths a mix of helium and oxygen is

used to reduce the gas density, but also to inhibit the narcotic effect of nitrogen in air at pressures corresponding to 40-50 meters below the surface.
The increased work used for breathing gives increased load for the respiratory muscles combined with the increased resistance of breathing connected with the diving equipment and immersion. Hypoventilation may lead to both hypoxemia and carbon dioxide retention which may reduce the mental awareness and performance.

Inert gasses

Gasses which are not metabolic active are described as inert gasses. Nitrogen has been mentioned as a narcotic gas at increased pressures. Helium has within the depths which are relevant for saturation diving no known narcotic effects. Hydrogen, which has been used for experimental diving, has also narcotic effects. The aetiology of HPNS (High Pressure Nervous Syndrome) is not known, but inert gases as nitrogen may modify the syndrome.

Ambient medium

Diving may take place in both dry environments in pressure chambers and in water as mentioned. There may be pollution both in chamber/breathing gas and in water which you need to take into consideration. Diving may take place in environments with chemical, bacterial and radioactive pollution. Bacterial pollution can originate from both the external milieu and from the water-processing systems which supplies the divers.
To maintain the thermal balance is a problem in water, and if helium is a part of the gas-mixture you loose more heat, because of the thermal properties of helium.

Breathing gas pollution

Compressed air used for filling of gas cylinders and supply for helmet-divers may be polluted by exhaust gas and oil products from the compressor. Pollution by carbon monoxide may be especially dangerous.
For the atmosphere in diving-bells, pressure chambers and breathing gas in closed systems there are special requirements for purity. If adequate gas-purifying filters are not used, there may be a congestion of carbon monoxide from the endogenous production and components which are brought into the chambers may liberate gases.
It may be so that the toxicity of some pollutants are increased by high pressure in itself and especially in combination with increased partial pressure of oxygen, but there exists only sparse data about this topic.

Psychological stress associated with diving

Diving take place in a milieu which is not adjusted for man kind, and we are dependent on technical equipment to maintain essential life functions as ventilation and thermal balance. Failure of equipment may bring the diver in life threatening situations. In addition to the specific dive-related equipment there are conditions in the environment at the work place under water and conditions connected to the support functions which are necessary for the diver so he can perform his task, and if these conditions fail it may bring the diver in dangerous situations.

Deaths in connection with diving in the North Sea were common in the 70s. Most of the deaths were connected to failure of equipment, wrong usage of equipment and failure of procedures. In this field there has been a big improvement, there has not been any deaths in connection with diving in Norwegian part of the North Sea since 1987.

Episodes connected to failure of diving equipment

To be able to work under water the diver need breathing gas supply, thermal protection and communication with the surface crew. Pipes and cables for gas, hot water and communication are twisted together to a umbilical which supplies the diver from the surface or the bell during surface-oriented, bounce or saturation diving. Supplies from the umbilical need to be integrated into the divingmask/helmet, breathing valve and diving-suit. Failure may result in dramatic situations as stop of gas supply and sudden hypothermia. Locking devices for the helmet against the suit and umbilical towards the suit may fail.

Episodes connected to ambient conditions and activity

Diving may take place at complicated installations with ongoing surrounding activities. There is a danger of fastening of the diver or bell, and danger of uncontrolled falling objects caused by work accidents connected to the surrounding activity. Equipment and diver may get trapped and become stuck either because of the operation the diver self is doing or by uncontrolled falling objects. Some parts of the diving operations are done in shallow waters where there is a danger of coming to close to propeller blades.

Episodes connected to colleagues and surface crew

The diver in the water is not only depended on that the technical equipment is functional satisfactory, but also on qualified personnel which operates the equipment. Human failure may lead to potentially dangerous situation as if the diver receives the wrong gas, is exposed to uncontrolled pressure variations or uncontrolled handling of the diving bell.

Episodes connected to stressful tasks/search for casualties

Very many divers have taken part in search for casualties. This could have been on duty from the police or it could be in connection with diving accidents were colleagues have been involved.

One special form of stress has for some been to be threatened by dangerous animals like sharks or rays, or be threatened by colleagues who are in psychic unbalance.

Results from the examinations at Haukeland University Hospital

Subjective health and quality of life reporting

Of the 165 northsea divers, who were referred because of health problems, were 96 examined per Mars 2004. The total number of former northsea divers is estimated to 375.

The group of examined divers had the same average age and diving-education as the group of diving controls (non-examined divers). There were significant differences between these two groups which indicate a greater cumulative diving-exposure of the examined group. The examined divers started as divers in average 2 years before the other group, and they were more exposed to all types of diving except of "bounce" diving. They had also experienced decompression sickness more often.

Their present alcohol habits were similar to the controls, but several divers had high alcohol consumption (> 18 units per week) in the period they were working as divers. The examined divers reported a higher usage of services like physiotherapist, doctor, and psychologist. They reported more often lost income and higher expense in connection to medical treatment.

The examined divers were infrequently married or living with someone compared to the controls.

The incidence of mental problems, tremors, numbness, pain, dizziness, tinnitus, concentration problems, forgetfulness, irritability and arthralgias were significant higher in both the examined divers and non-examined divers compared to the controls from the general population. When we at the same way compare the whole population of northsea divers with the controls from the general population we see significant higher incidence of palpitations, pressure in the chest, weakness in hands and feet, depression, anxiety, sleeplessness, headache and low-back pain in the population of divers.

There were significant fewer persons among the divers who were satisfied with their health and quality of life compared with the general population.

Lung function

There were totally 34 out of 96 examined divers who reported at least two airway symptoms, either continuous coughing, dyspnoea at physical activity or wheezing.

FVC was compared with the Norwegian expectable values normal, while the group had a FEV_1 which was significant lower than expected, Table 1. The portion of the divers with airway obstruction (FEV_1 < 80% and FEV_1/FVC ratio < 0.7) was 5.1% towards the expected 1.8%.

The diffusion capacity of the lungs was somewhat lower than expected.

Table 1

Lung function entities	Absolute value	% of expected Norwegian value	% of expected European value	p-value
FVC (liter)	4.99 ± 0.83	96.7 ± 13.5	107.6 ± 14.3¤	p<0.01¤
FEV_1 (liter)	3.66 ± 0.71	86.3 ± 14.7*	97.8 ± 16.3	p<0.001*
FEV_1/FVC (%)	73.3 ± 6.9	88.4 ± 12.6*	93.7 ± 12.8¤	p<0.001*¤
$FEF_{25-75\%}$ (liter/s)	3.00 ± 1.00		75.4 ± 30.1¤	p<0.001
PEF (liter/s)	8.92 ± 1.80		99.5 ±19.7	
TLC (liter)	7.45 ± 0.99		103.0 ±13.8	
FRC (liter)	3.67 ± 0.81		103.4 ± 15.3	
RV (liter)	2.33 ± 0.71		105.5 ± 22.5	
RV/TLC (%)	34.0 ± 2.7		103.9 ± 8.0¤	p<0.05
SVC (liter)	5.08 ± 0.85		104.9 ± 15.1	
Tl_{CO} (mmol/min/kPa)	10.34 ± 2.05	95.1 ± 13.9*	99.4 ± 14.1	p<0.05*
K_{CO}(mmol/min/kPa/l)	1.48 ± 0.29			
V_A (liter)	7.05 ± 0.98			

Neurological symptoms and findings

74 divers had one or more neurological findings. This gives a incidence of 19.3% if the number of findings are divided on the calculated number of 375 northsea divers. 35 divers in the group were aged 50 or less, and out of these 74% had one or more neurological findings.

The result from the clinical neurological examination showed that sensibility loss, failing coordination and cerebellar dysfunction are the most common findings in more than 40% of the examined divers. Reflex asymmetry was proved in 33% of the divers. Those reflex examinations which may show possible central damage of the divers indicate changes in 40% (eg. hyperreflexia, weakened abdominal reflex).

Table 2. Summery of neurological signs

	Number of divers with abnormal findings	Portion of 96 divers (%)	Portion of 375 divers (%)
Mental status	23	24,0	6.1
Cranial nerves	16	16.7	4.3
Motility	33	34.4	8.8
Coordination and cerebellar tests	42	43.8	11.2
Sensibility	45	46.9	12.5
Gait	8	8.3	2.1
Reflex asymmetry	28	29.2	7.5
Reflex changes(centrally determined)	40	41.7	10.7

There was not proved any associations between neurological findings and cardiovascular diseases, head trauma, alcohol consumption or age.

In table 3 the incidence of neurological findings is compared with the control group from the general population. There are significant differences in all the parts of neurological examination, except for the cranial nerve examination.

Table 3

	Divers N= 96 (%)	Controls N=52 (%)
Mental status	24.0	0.0
Cranial nerves	16.7	5.8
Motility	34.4	5.8
Coordination and cerebellar tests	43.8	5.8
Sensibility	46.9	1.9
Gait	8.3	0.0
Reflex asymmetry	29.2	19.2
Reflex changes (central)	41.7	21.2

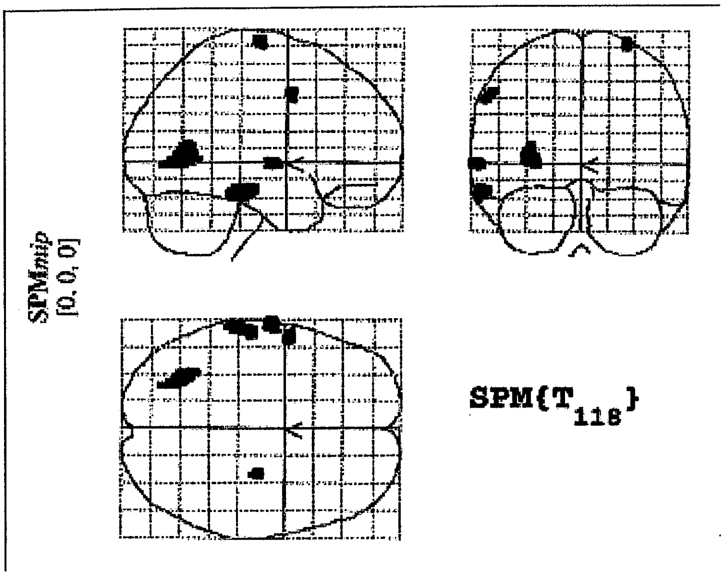
Clinical neuro-physiology

16% of the examined divers had pathological or mild pathological EEG. In the normal population there were only 2.4%. During the EEG there is a striking feature that the divers very quickly develop drowsiness. After only few minutes with the eyes closed appears very often changes in the EEG-curve which notifies beginning of sleep. This is much more frequently than in the control group.

Neuro-radiological examination (MRI)

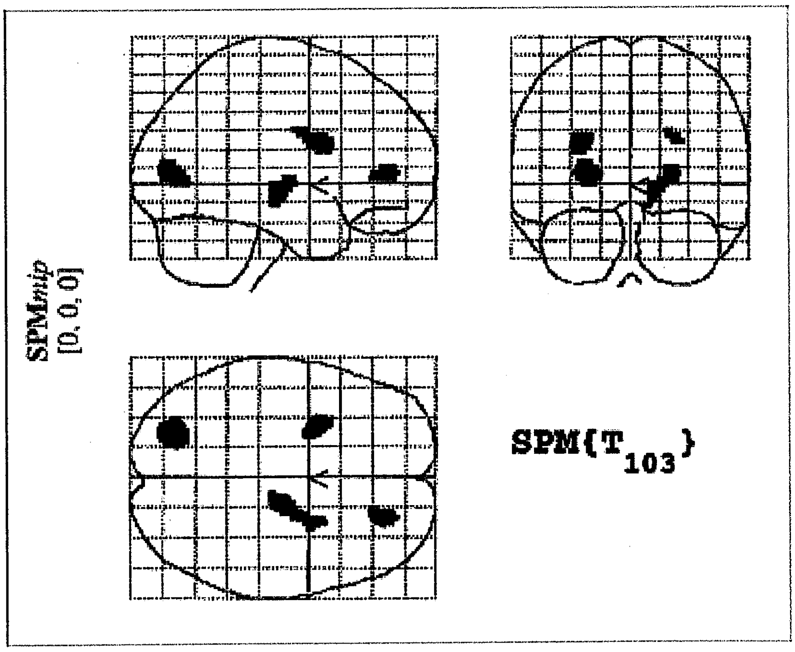
Volume analysis of brain tissue showed that the group of divers had reduced grey substance superficially in left temporal lobe in a patchy pattern and centrally in left occipital lobe (white matter).

Figure 1. Areas where the divers have less amount of tissue are marked.



When comparing the perfusion of brain tissue between the divers and the controls there is clearly seen a reduced perfusion in the divers, localized centrally in the frontal lobe and the left occipital lobe.

Figure 2. Areas where the perfusion is lower in the divers are marked.



Neuro-psychological examination

The examined divers had normal mental capacity and were able to manage complex problem-solving when the task had no special time limit. Average performance as regards motor tempo, power and steadiness were normal. The results on the steadiness tasks were however not normally distributed and a selection of the divers had prominent tremor. The group of divers as a whole showed weaker performance than expected on tasks which demand attention, concentration, working memory, mentally tempo and flexibility, and high grade handiness.

Psychological stress reactions

Only 3 out of the examined divers reported that they never had been involved in life threatening situations during diving. 37% had been involved in such episodes more than 5 times, while 39% of the divers had been involved 1 to 5 times, and 23% had no definite numbers.

Table 4. Episodes experienced by the divers

Type of incidence	Number (%) responders
Stop of gas/air	46(56.8%)
Fastening	39(48.1%)
Falling objects	33(40.7%)
Leeway	25(30.9%)
Hypothermia	20(24.7%)
Uncontrolled handling of the bell	16(18.5%)
Wrong gas mixture	12(14.8%)
Lost mask/helmet	10(12.3%)
Uncontrolled surfacing	9(11.1%)
Explosion	7(8.6%)
Propeller nearby	7(8.6%)
Attack by human or animal	4(4.9%)

81.5% stated that they had seen a colleague in mortal danger, 23 divers had been a witness to such a situation more than 5 times, 22 divers from 1-5 times, while 36 had no definite numbers. 28.4% reported that such episodes had lead to death.

The group's average score is lower than the limit value for Keane's PTSD scale, but 27% of the divers exceeded the limit. MMPI scores indicate that the group manifests generalized problems in the direction of depressive complains, somatic and psychosomatic complains, anxiety and worry for their own cognitive function.

Conclusions

Deep sea diving is a great risk factor for both acute and chronic problems. During the early age of deep sea diving the control and knowledge of risk factors were not that great. These factors and long term effects have been revealed in more detail in the last years. Better procedures and equipment are produced and are a part of the tasks to limit the occupational hazards of diving.

Divers long term effects includes entities as subjective feeling of lower quality of life, decreased lung function, neurological changes, cerebral tissue and perfusion changes, EEG changes, attention and concentration problems, mental changes, anxiety, depression, PTSD and pain.

The future will show if the decrease in duration of life in divers also is a long term effect.

References

Thorsen E, Troland K, Sundal E, Gronningen, M. Health status of former northsea divers. Report of 2004. Occupational Department, Haukeland University Hospital.

Hope A, Lund T, Elliott DH, Halsey M, Wiig H. Long term health effects of diving. An international consensus conference. Godøysund 6.-10. June 1993. John Grieg forlag A/S, Bergen 1994: 387-391.

Health & Safety Executive. Co-ordinated investigation into the possible long term health effects of diving at work. Prepared by University of Aberdeen for the Health & Safety Executive. Research Report 230, 2004.

Thorsen E, Hjelle J, Segadal K, Gulsvik A. Exercise tolerance and pulmonary gas exchange after deep saturation dives. J Appl Physiol 1990; 68: 1809-1814.

Thorsen E, Risberg J, Segadal K, Hope A. Effects of venous gas microemboli on pulmonary gas transfer function. Undersea Hyperbaric Med 1995; 22: 347-353.

Skogstad M,Thorsen E, Haldorsen T, Kjuus H. Lung function over six years in professional divers. Occup Environ Med 2002; 59: 629-633.

Francis TJR, Mitchell SJ. Manifestations of Decompression Disorders. In: Bennett and Elliott's Physiology and Medicine of diving (eds. Brubakk AO, Neuman TS). Saunders, Edinburgh, 2003: 578- 599.

Todnem K, et al. Akutte og kroniske effekter på nervesystemet ved dypdykking. Tidsskr Nor Laegeforen 1993; 113: 36- 39.

Todnem K, et al. Influence of occupational diving upon the nervous system: an epidemiological study. Br J Ind Med 1990; 47: 708- 714.

Værnes RJ , et al. Neuropsychologic effects of saturation diving. Undersea Biomed Res 1989; 16: 233- 251.

Værnes R et al. CNS reactions at 51 ATA on trimix and heliox and during decompression. Undersea Biomed Res 1985; 12: 25-39.

Palmer AC, Calder IM & Yates PO (1992) Cerebral vasculopathy in divers. In EUBS Annual Scientific Meeting pp. 137 –144. Ed. W. Sterk & L. Geeraedts. Amsterdam: European Undersea Biochemical Society.