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# Reduced health-related quality of life in former North Sea divers is associated with decompression sickness

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**Background** Diving is associated with long-term effects on several organ systems.

**Aim** The objective was to investigate the impact of decompression sickness (DCS) and diving exposure on health-related quality of life (HRQL) in former Norwegian North Sea divers.

**Methods** HRQL was recorded by a questionnaire in the cohort of 375 Norwegian North Sea divers registered before 1990. Demographic data, relevant health data and data on diving education, history of DCS and SF-36 were recorded in 230 divers.

**Results** All SF-36 sub-scores were significantly reduced compared with Norwegian norms. Reduced scores were seen for all scales among divers who reported previous DCS compared to those without DCS. A decreasing trend in scores was seen when comparing no DCS, skin or joint DCS and neurological DCS. There was a decreasing trend in scores related to number of days in saturation and maximal depth. Stratification on DCS showed that the impact of saturation diving was present only in divers with DCS.

**Conclusions** HRQL was reduced in this study sample of divers. Having had DCS during the diving career contributed significantly to the reduction in all SF-36 scales, and apparently neurological DCS has the most pronounced impact. Cumulative diving exposure including days in saturation and maximal depth contributed to a reduced HRQL.

**Key words** Decompression sickness; diving; occupational disease; quality of life; SF-36.



## Introduction

Diving is associated with exposure to hyperoxia and a decompression stress that may cause gas micro bubbles and decompression sickness (DCS). Toxic effects of hyperoxia on the lung are well known [1]. DCS may manifest as skin and joint pain, or as acute neurological symptoms. Permanent sequelae have been demonstrated in 20–30% of the cases with neurological DCS [2]. In addition, diving is associated with increased risk of aseptic bone necrosis and hearing impairment [3,4]. Cross-sectional studies of professional divers have demonstrated effects on lung function and on the central nervous system associated with cumulative diving exposure and DCS [4–11].

Assessing the patient's perspective in the evaluation of the burden of disease has become common during the past decades. Self-reported health-related quality of life (HRQL) has been used for a number of purposes, including clinical studies and population monitoring. The Medical Outcomes Study Short-Form General Health Survey (SF-36) is widely used and validated in medical research [12]. Until the early 1990s, such methods had not yet been included in any of the studies of divers' health. Increased prevalence of some symptoms reported in these previous studies might, however, indicate a reduced HRQL [4–11]. Still, one of the conclusions made by the international consensus conference on long-term health effects of diving in 1993 [13] was that changes observed in different organ functions did not influence the diver's quality of life.

The aim of the present study was to investigate the impact of diving exposure and particularly DCS on present HRQL as assessed by the SF-36.

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## Methods

A cross-sectional study was performed in a cohort of North Sea divers. All divers gave their informed consent. The Regional Ethical Committee for Medical Research and The Data Inspectorate approved the study. The target population was Norwegian divers starting their offshore diving career before 1990. Official records obtained from the Norwegian Ministry of Labour and Social Affairs [14] identified a cohort of 375 divers. Of these, some had been referred to hospital for diving-related problems. They filled in a questionnaire and SF-36 before attending any examination. Inclusion of divers to this study ended in March 2004 when the Norwegian Parliament approved compensation for North Sea divers with health problems, and 16% of the cohort was still waiting to be examined at that time. To avoid referral bias, the same questionnaire was mailed to the divers within the cohort who had not been referred to hospital.

Demographic data, relevant health data and data on diving education were recorded by a questionnaire. The questions included were marital status (married, single, widower, cohabited or divorced), education (primary school only, theoretical college, technical college, university college, university), present working situation (full-time work, part-time work, unpaid work, self-employed, rehabilitation, unemployed, long-term time sick leave, recipient of disability benefit), smoking (never smoked, present smoker, previous smoker), alcohol consumption (none, <6, 6–12, 13–18, 19–24 and >25 units per week), diving education (recreational diving, military diving, occupational diving, other), previous or present illnesses (allergy, sinusitis, asthma, hypertension, heart disease, diabetes, fractures, concussion or head injury, other sort of neurological damage, epilepsy, migraine, arthritis, cancer and psychological problems).

Data on cumulative diving exposure and previous DCS were collected in a questionnaire as well. The questions included were years of diving, number of air bounce dives, number of days in saturation, number of mixed gas bounce dives, maximal depth, DCS (yes, no), type of DCS (skin/joint, neurological, other). For each diving exposure variable, a new, categorized variable was computed, using median, upper and lower quartiles as cut points.

HRQL was assessed by the SF-36 [12,15]. The following scales from SF-36 were studied: Role-Physical (RP), Bodily Pain (BP), General Health (GH), Vitality (VT), Role-Emotional (RE) and Mental Health (MH). Social Functioning (SF) was based on social extent, and Physical Functioning was based on physical restriction to vigorous, moderate or easy activities. SF-36 normative data from the general Norwegian population [16] were used for comparison. Higher scores indicate a better HRQL. Mean norms for males in the age group 40–59 years were calculated on the basis of the norms for the age groups 40–49 and 50–59 years.

Comparisons with Norwegian SF-36 norms were done by one-way Student *t*-test with the Norwegian norms as reference. Univariate analysis of variance was used to test hypotheses of differences in SF-36 sub-scores for divers with and without previous DCS. Due to prevalence differences of concussion or head injury, other neurological disorder and psychological problems in divers with and without DCS, adjustments were made for these. The same methods and adjustments were used to test the hypothesis of a decreasing trend in scores when comparing no DCS, skin or joint DCS and neurological DCS. Univariate analysis of variance was used to test hypotheses on SF-36 scales scores associated with a trend in diving exposure. In these analyses, no adjustments were done, since the prevalence of illnesses was similar among exposure groups. In addition, stratified analyses were done for divers with and without DCS.

Statistics on demographic factors in the sub-group of referred divers (RD) and non-referred divers (NRD) were tested by exact Pearson chi-square test and in diving exposures by Mann–Whitney *U*-test. All the corresponding hypotheses stated above were tested for each of these sub-groups. The statistical program SPSS 13.0 [17] was used.

## Results

Of the former North Sea divers, 104 had been referred to hospital for diving-related problems. In this study, eight were excluded. Seven had not dived offshore and one refused to participate in the study. Ninety-six RD were included. Of 210 divers who were not referred to hospital, 134 (NRD) responded (response rate 64%). The total number of divers included in the study was 230, of whom 41% had been referred to hospital. The mean age in the study sample was 52 years (SD 6.7). All were men. The study sample demonstrated reduced scores on all SF-36 scales when comparing with the Norwegian norms (Table 1).

Divers with a history of DCS reported considerably lower scores for all scales than divers with no history of DCS (Table 2) both before and after adjustment for concussion or head injury, other neurological disorder and psychological problems.

When comparing sub-scores in divers without DCS, in divers with a history of skin/joint DCS and in divers with neurological DCS, decreasing linear trends were seen for all scales (Table 3). The linear trends remained after adjustment for concussion or head injury, other neurological disorder and psychological problems and for the scales RP, GH, VT, SF and MH. For all scales, the differences between score for each type of DCS and non-DCS were significant at the 5% significance level.

Several hypotheses regarding decreasing linear trend in SF-36 scores with increasing diving exposures were tested. A decreasing linear trend was shown for the scale

**Table 1.** HRQL, SF-36 for scales compared to Norwegian norms for men aged 40–59 in 230 divers, Norway 2004

| SF-36 scale score | SF-36 norms | Divers |
|---|---|---|
| | Mean | Mean (SD) |
| RP | 83 | 70 (35)*** |
| BP | 76 | 61 (30)*** |
| GH | 77 | 56 (28)*** |
| VT | 64 | 55 (29)*** |
| SF | 87 | 67 (37)*** |
| RE | 88 | 78 (32)*** |
| MH | 80 | 75 (23)** |

**$P < 0.01$, ***$P < 0.001$.

**Table 2.** HRQL, SF-36, in 230 divers for scales among divers having and not having experienced DCS, Norway 2004

| SF-36 scale scores | No DCS | DCS | Crude | Adjusted[a] |
|---|---|---|---|---|
| | Mean (SD) | Mean (SD) | *P*-value | *P*-value |
| RP | 88 (32) | 62 (32) | *** | *** |
| BP | 72 (30) | 56 (30) | *** | * |
| GH | 72 (25) | 48 (26) | *** | *** |
| VT | 70 (27) | 49 (27) | *** | *** |
| SF | 84 (36) | 61 (36) | *** | * |
| RE | 91 (30) | 73 (31) | *** | * |
| MH | 84 (22) | 71 (23) | *** | * |

[a]Adjusted for concussion or head injury, other neurological disorder and psychological problems.

*$P < 0.05$, ***$P < 0.001$.

**Table 3.** HRQL from SF-36 scales for 230 divers having and not having experienced various types of DCS, test for linear trend, Norway 2004

| SF-36 sub-scale score | DCS | | | | |
|---|---|---|---|---|---|
| | None | Skin or joint | Neurological | Crude | Adjusted[a] |
| | Mean (SD) | Mean (SD) | Mean (SD) | *P*-value | *P*-value |
| RP | 86 (32) | 63 (33) | 58 (33) | *** | *** |
| BP | 71 (29) | 56 (29) | 56 (29) | * | |
| GH | 72 (25) | 49 (26) | 45 (25) | *** | *** |
| VT | 68 (28) | 51 (27) | 44 (28) | *** | *** |
| SF | 81 (36) | 65 (36) | 48 (37) | *** | * |
| RE | 90 (31) | 73 (31) | 75 (30) | * | |
| MH | 82 (23) | 73 (23) | 65 (23) | *** | ** |

[a]Adjusted for concussion or head injury, other neurological disorder and psychological problems.

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

BP ($P = 0.007$) for increasing years of diving. For number of mixed gas bounce dives, a linear trend was seen for RP ($P = 0.02$). For number of air bounce dives, trends were demonstrated for the scales BP ($P = 0.04$) and SF ($P = 0.03$). With increasing maximum depth, decreasing trends were seen in the scales BP ($P = 0.047$), GH ($P = 0.007$), VT ($P = 0.04$), SF ($P = 0.02$), RE ($P = 0.02$) and MH ($P = 0.03$). For days in saturation, trends were seen for all scales: RP ($P = 0.001$), BP ($P = 0.003$), GH ($P < 0.001$), VT ($P = 0.002$), SF ($P < 0.001$), RE ($P = 0.001$) and MH ($P = 0.002$).

Stratified analyses were done for divers with and without DCS. For divers without a history of DCS, no trend in scores was seen with increasing diving exposures for any of the scales. Among divers with DCS, the most consistent finding was for increasing number of days in saturation where decreasing linear trends in scores were seen for the scales RP ($P = 0.005$), BP ($P = 0.04$), GH ($P = 0.02$), VT ($P = 0.02$), SF ($P = 0.02$) and RE ($P = 0.03$).

The corresponding hypotheses were tested in RD and NRD. In these groups, no age difference was seen. The educational level, smoking status and alcohol consumption were similar. The proportion of divorced was higher in RD, 22 versus 12% in NRD ($P < 0.05$), the proportion in full-time employment was lower in RD, 23 versus 72% in NRD ($P < 0.001$), and a higher proportion of RD received a disability pension, 35 versus 8% in NRD ($P < 0.001$). Differences were also seen in diving exposure (Table 4), and RD reported DCS more frequently than NRD. There were no differences in diving education.

RD had reduced HRQL in all SF-36 scales ($P < 0.001$) compared to Norwegian norms. In the NRD group, however, only the GH score was reduced compared to these norms ($P < 0.002$).

Among RD, the majority reported DCS (90%) and a reduced HRQL, and no difference in sub-scores could be demonstrated for divers with and without a history of DCS. In NRD, 55% had experienced DCS, and reduced SF-36 scores within this group were seen for RP ($P < 0.01$), GH ($P < 0.001$) and VT ($P = 0.01$), which all remained significant after adjustments for concussion or head injury, other neurological disorder and psychological problems.

Hypotheses for trends in scores for divers without DCS, divers with a history of skin/joint and divers with neurological DCS were tested for RD and NRD separately as well. For RD, a trend was seen for BP ($P < 0.05$) in the unadjusted analysis, but was no longer significant after adjustments. In NRD, a decreasing trend was demonstrated for the scales RP ($P < 0.01$), GH ($P < 0.001$), VT ($P < 0.05$) and SF ($P < 0.01$). After adjustments, all these trends remained significant.

## Discussion

In this study, all SF-36 sub-scores were reduced in the divers compared to the Norwegian norms. DCS was

**Table 4.** Reported diving experience and DCS in 96 RD and 134 NRD, Norway 2004

| Reported diving experience | RD | | NRD | | P-value |
|---|---|---|---|---|---|
| | Median | Range | Median | Range | |
| Year of diving | 15 | 3–38 | 11 | 1–47 | ** |
| Number of air dives | 1000 | 101–17000 | 500 | 2–20 000 | *** |
| Days in saturation | 300 | 0–2000 | 90 | 0–1600 | ** |
| Number of bounce dives | 26 | 0–1001 | 10 | 0–2000 | |
| Maximal depth ever | 170 | 85–500 | 150 | 50–450 | *** |
| Reported DCS | *n* (%) | | *n* (%) | | Exact *P*-value |
| Never DCS | 10 (10) | | 59 (44) | | *** |
| DCS of the skin | 50 (52) | | 31 (23) | | *** |
| DCS of joint | 60 (63) | | 52 (39) | | *** |
| Neurological DCS | 18 (19) | | 15 (11) | | |

**$P < 0.01$, ***$P < 0.001$.

associated with a reduction in HRQL. Reduced subscores were seen for all scales in divers with DCS compared to divers without previous DCS. The various SF-36 scales were reduced differently depending on what type of DCS the diver had experienced. Neurological DCS appear to affect HRQL more seriously than skin or joint DCS.

A high percentage of the available cohort, 75%, was included, which is one of the strengths of this study. The total number of previous Norwegian North Sea divers, 375, have been questioned. However, it is expected that most of the North Sea divers, who have been diving for some time, are included [14].

In this study, the well-known international instrument, SF-36, was used to evaluate HRQL. This instrument has been translated to Norwegian, been validated and norms are established based on a random sample of the Norwegian population. The SF-36 [12] has previously proven useful both in surveys of general and selected populations, comparing the relative burden of disease, and in differentiating the health benefits produced by a wide range of different treatments.

In this study, another advantage was the opportunity to study both the RD and NRD. The latter group, which we expect have less information bias, was of particular interest.

The relatively small sample size is a limitation, which may explain the inconsistency of the findings when linear trends in diving exposures were analysed separately for RD and NRD. For several diving exposure variables, trends were not obvious. The lack of significant linear trends by a specific type of diving exposure may indicate that this has minor impact on later HRQL. Alternative explanations are that the diving exposure took place several years ago and the data may be hampered by recall bias, which may mask an association, or the quality of the variables may be poor and burdened by misclassification and missing data, which may also mask an association. For number of days in saturation, the stratified analysis on DCS status indicated that there might be an association with a history of DCS. The problem of misclassification of DCS is probably of another nature. Traditionally, DCS has been categorized as Type I (DCS affecting skin, joint) and Type II (spinal or neurological DCS). The reduced HRQL in divers who reported skin or joint DCS, might be explained by misclassification if these divers ignore reporting neurological symptoms due to severe symptoms in skin and joints. Previous studies have shown that the understanding of neurological DCS among divers has changed while the North Sea divers were occupationally active [18,19].

In the analysis of the association between DCS and HRQL, we adjusted for concussion or head injury, other neurological disorder and psychological problems since these varied within DCS groups. Adjusting for these may be questionable, since diving might have caused the reported illness, and should not be looked upon as a confounding factor. The same argument was used when factors like marital and occupational status were not included in the analysis [20]. Both marital and occupational status might be related to diving as an intermediate step on the pathway to outcome.

In March 2004, the Norwegian Health Authorities decided to award compensation to all divers with health problems, i.e. both RD and NRD. To avoid information bias, inclusion to the study was stopped after this decision was made. Thus, 16% had been referred, but were not included in the study. If they had been included, the sample size and the statistical power would have increased but with the risk of biasing the results.

Until the early 1990s, HRQL had not yet been included in any of the studies of divers' health. However, increased prevalence of some symptoms reported in some of these studies may indicate a reduced HRQL. Our study demonstrated a decreasing trend for all scales of SF-36 when comparing the scores in divers with no reported DCS, skin or joint DCS and neurological DCS. The findings are in accordance with previous studies of saturation divers [5,10], inshore divers [21], recreational divers [22] and a recent comprehensive epidemiological study of occupational divers [23].

The cumulative diving exposure is expected to influence later HRQL. We found that days in saturation and maximal depth were associated with subsequent reduced SF-36 sub-scores. For the remaining diving exposure variables, trends were not obvious. An association between diving exposure and HRQL was not found in the earlier studies. However, the exposure variable is complicated and not very well defined in most studies.

As expected, RD with identified medical complaints had a reduced HRQL. The reductions were seen in all scales of SF-36. The sub-score level for RD was lower than for several chronic health conditions like allergies, arthritis, chronic lung disease, hypertension or ischemic heart disease, diabetes reported in previous international studies and in a recent Norwegian study [24,25]. However, the scores were comparable to those of patients with multiple sclerosis, depression and chronic fatigue syndrome [26–28]. In NRD, we found a reduced GH score, which is unexpected as NRD is supposed to be a group of healthy and occupationally active men.

The purpose of this study was to investigate the extent of reduced HRQL in a diver population. Occupational divers in Norway have for many years been concerned with the high prevalence of symptoms and diseases among colleagues, which initiated this survey offering a comprehensive medical examination to all Norwegian divers who had been working in the North Sea before 1990 and claiming health problems for any reason. To avoid a selection bias, also divers, who were not referred, were invited to answer the questionnaire.

Our findings suggest that both clinicians and divers should take DCS seriously. During the last three decades, the use of mixed gas bounce diving in the North Sea has stopped, and the procedures for saturation diving have been improved. This has possibly contributed to the decreasing number of reported DCS in the oil industry since 1990 [29]. Proper treatment of DCS may further reduce adverse long-term effects. A thorough, periodical health service for all divers could be of importance if signs of deteriorating health were noticed and a program was established to handle this.

With a decreasing number of DCS reported in the oil industry since 1990, it would be of interest to study a cohort of divers who started diving after 1990. Attached to a health service program, a longitudinal study could be established to reveal, in more detail, factors associated with HRQL and other health effects and a possible improvement as well. An additional field of future research would be to improve characterization of diving exposure and thereby study the health effects of various diving techniques. We have studied offshore divers with extensive exposure to saturation dives to large depths but few studies have considered inshore divers who dive in shallow water, using other diving techniques.

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## Conflicts of interest

None declared.

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