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Health status of professional divers and offshore oil industry workers

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Aims To compare the health status of UK professional divers and age-matched non-divers and to contrast offshore divers (OSDs) with non-offshore divers (NOSDs).

Methods A postal survey sent to 2958 male professional divers, registered with the UK Health & Safety Executive (HSE) before 1991, and 2708 men who had worked in the offshore oil industry in 1990–92 (non-divers). The questionnaire addressed lifestyle, occupation and health status.

Results In all, 56% of divers and 51% of non-divers responded. Three per cent of participants reported ill-health retirement or being off-work on sickness benefit with no difference between groups. Divers were less likely to report asthma or hypertension. Health-related quality of life (SF-12) was within normal limits for both groups but the mental component summary was higher in divers who were also less likely to be receiving medical treatment. Divers were more likely than non-divers to report 'forgetfulness or loss of concentration' (18% versus 6%, OR 3.8, 95% CI 2.7–5.3), musculoskeletal symptoms (41% versus 34%, OR 3.8, 95% CI 2.7–5.3) and 'impaired hearing' (16% versus 11%, OR 1.6, 95% CI 1.2–2.0). These differences were attributable to increased symptom reporting in OSDs and were not present for NOSDs, with the exception of cognitive symptomatology which was commoner in both OSDs (22%, OR 4.8, 95% CI 3.4–6.8) and NOSDs (9%, OR 1.9, 95% CI 1.1–3.3) than in non-divers (6%).

Conclusions There was increased symptom reporting in OSDs. However, there was no evidence to suggest any major impact on long-term health of UK divers who had started their career before 1991.

Key words Diving; health status; occupation; quality of life; questionnaire.

Introduction

There is concern regarding unrecognized long-term health effects of a diving career. While decompression illness and dysbaric bone necrosis are recognized problems for divers, other problems have been identified. Musculoskeletal symptoms were noted in two studies [1,2]. Similarly, cognitive dysfunction was identified in Australian abalone divers [3] but this was not confirmed in a follow-up study [4]. There have been other conflicting reports of cognitive dysfunction in divers [5,6]. More consistent observations have been made in Norwegian commercial divers [7,8]. Todnem [7] reported that divers were more likely than controls to report difficulties in concentration and memory. More recently, a Norwegian Government Commission reported on the health of Norwegian divers working in the North Sea prior to 1991 [9]. There was a high prevalence of musculoskeletal and cognitive complaints and 40% reported some form of medical treatment which was for the reported complaints in 25%. The prevalence of disability pension was 2–4.2 times that of the age- and gender-adjusted background population. Subsequently, the Norwegian Government introduced a compensation package for accidental injury in this group of oilfield divers.

In view of this experience, we conducted an observational questionnaire study on UK professional divers who were working before 1991. The aims of the study were to identify differences in health status between divers and a control group of non-diving offshore workers (non-divers), to examine the level of disability in divers

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both in general and in those who had worked in the offshore oil industry.

Methods

A lifestyle, work and health status questionnaire was posted to divers and non-divers in 2000/2001, and non-responders were sent repeat questionnaires a total of three times, at monthly intervals. No incentives were offered. The study was given a favourable opinion by the Grampian Regional Ethics Committee. Divers who started their diving career prior to 1991 and were registered with the Health & Safety Executive (HSE) were selected for the study. This criterion, which meant that they had worked in the diving industry 9–10 years prior to the study, gave time for occupation-related symptoms and clinical conditions to manifest. Divers were traced using identity and contact data from the HSE, the Community Health Index, commercial tracing (Data Discovery Ltd) and other sources of publicly available information. An age-matched control population of male non-divers was recruited from offshore workers who had passed a fitness to work medical examination in 1990–92. Non-divers were required never to have dived, either professionally or recreationally. Their addresses were traced using the methods described for divers.

Alcohol consumption and smoking habit were reported as described in Table 1. Educational attainment was defined as the highest educational qualification obtained. The Carstairs deprivation index was assessed based on the participants' postcode, using small-area census data [10]. Height and weight were reported in the questionnaire from which body mass index (BMI) was calculated.

Divers reported the duration of their diving career and if they had worked offshore. Non-divers reported the duration of their career as an offshore worker. Both groups reported their current employment status which referred to any occupation.

Divers were asked to detail their use of the five different diving techniques: self-contained underwater breathing apparatus (SCUBA) diving, surface-supplied air diving (SSAD), surface oxygen decompression diving ($SurDO_2$), mixed gas bounce diving (MGBD) and saturation diving (SD). These techniques differ in terms of decompression stress and give an indication of the type of industrial environment in which the diver has worked. SCUBA and SSAD are typically associated with inshore and coastal diving. $SurDO_2$, MGBD and SD are almost exclusive to the oil and gas offshore industry.

The respondents rated the severity of symptoms from a list of complaints. Current suffering of symptoms were rated on a four-point scale (0–3) from 'not at all', 'slightly', 'moderately' to 'extremely'. The expression of symptoms was assessed in three ways. Participants were grouped as non-sufferers ('not at all' or 'slight') and sufferers ('moderate' or 'extreme'). The number of

Table 1. Characteristics of divers and non-divers

	Divers (n = 1540)	Non-divers (n = 1035)
Age [mean (95% CI, median)]	45.4 (45.0–45.8, 44.0)	45.1 (44.8–45.6, 44.0)
Smokers		
Current smoker	305 (20%)	297 (29%)
Ex-smoker	252 (34%)	281 (27%)
Pack years for current or ex-smokers [median (iqr)][a]	11 (5–21)	19 (10–30)
Binge drinking alcohol[b]		
Never	215 (14%)	99 (10%)
Less than once a month	348 (23%)	185 (18%)
1–9 times a month	690 (45%)	548 (53%)
10–20 times per month	195 (13%)	148 (14%)
>20 times per month	50 (5%)	50 (5%)
Carstairs scores (median, iqr)	−1.9 (−2.9 to −0.6)	−1.8 (−3.1 to 0.1)
Educational qualifications		
None	252 (16%)	147 (14%)
O level or equivalents	683 (44%)	378 (37%)
A level or equivalents	136 (9%)	89 (9%)
Higher National Certificate or Diploma	199 (13%)	201 (19%)
University degree	247 (16%)	202 (20%)
BMI (kg/m^2) [mean (95% CI, median)]	26.6 (26.4–26.8, 26.1)	26.7 (26.4–27.0, 26.0)
Head injury (self-reported)	262 (17%)	93 (9%)

[a]Pack years—cigarettes per day times years smoked divided by 20.

[b]Binge drinking—eight or more UK units of alcohol on one occasion.

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participants suffering four or more symptoms was determined. Tendency to express symptoms was assessed by a symptom tendency score compiled by adding scores for each of the 11 symptoms elicited to give a maximum score of 33. Internal consistency was sufficient to allow its use to compare the groups (Cronbach's alpha 0.83). Similar scoring systems have been used elsewhere to assess somatization [11]. The two musculoskeletal symptoms elicited ('joint pain or muscle stiffness' and 'neck or back pain') were collapsed into one variable after calculation of the symptom tendency score.

Participants reported diagnosis of any of a list of medical conditions, whether they had suffered a head injury and whether they were receiving any form of medical treatment. As part of the questionnaire, the SF-12 was completed, providing a measure of health-related quality of life (HRQOL). Two components are generated from the SF-12, a mental health component summary (MCS) and a physical component summary (PCS). Both components are standardized to give a normative population mean score of 50 with a standard deviation of 10 [12].

A summary of the study populations' characteristics is shown in Table 1. The two groups were age matched and ranged from 27 to 76 years in age. Divers had dived professionally for a mean of 14.9 (95% CI 14.5–15.3) years with a range of <1 to 44 years. Forty-one per cent of divers had dived professionally for >15 years and 47% of non-divers had worked offshore for >15 years. Forty-five per cent of divers had not dived in the past year and 28% had not dived in the past 8 years. Of the 881 divers identified as working in the offshore oil industry, 50% had started their commercial diving career during or before 1979. Thirty-six per cent of divers reported decompression illness with 11% suffering neurological disease and 32% non-neurological illness.

The data set was examined for non-responder bias by looking for differences between responses from the three mailings [13]. One-way analysis of variance or the Kruskal–Wallis test was used as appropriate. Analysis was then carried out in two stages.

In Stage 1, the prevalence of symptoms and diagnosed medical conditions of divers and non-divers were compared using adjusted logistic regression analysis (Tables 2 and 3). SF-12 scores between groups were assessed by analysis of covariance allowing for age, frequency of binge drinking alcohol, pack years and BMI. Changes in HRQOL associated with diagnosis or symptom reporting were assessed by calculation of the effect size using Cohen's d [14]. An effect size (d) of 0.2 is regarded as small, 0.5 medium and over 0.8 large. Symptom tendency score was assessed by Mann–Whitney U-test and report of four or more symptoms by chi-square test.

For Stage 2, divers were grouped into non-offshore divers (NOSDs) and offshore divers (OSDs), according to the diving techniques they used and whether they reported having worked offshore (Table 4). NOSDs had only used SCUBA or SSAD (n = 257). OSDs had used SurDO_2, MGBD or SD (n = 881). Comparison of the two diving groups with non-divers was conducted using adjusted binary logistic regression models (Table 5).

For chi-square testing with continuity correction, 1500 divers and 1000 non-divers were required to give 80% power at the 0.05 probability level to detect differences of 2–6% between groups.

SPSS for Windows (version 14.0, SPSS Inc., Chicago, IL) was used for all data analyses.

Table 2. Comparison of the prevalence of diagnosed medical conditions between divers and non-divers

	Subjects with the condition n (%)		Adjusted OR mean (95% CI)[a]
	Divers	Non-divers (reference)	
Asthma	78 (5%)	73 (7%)	0.70 (0.49–0.99)
High blood pressure	156 (10%)	129 (13%)	0.73 (0.56–0.98)
Arthritis	136 (9%)	64 (6%)	1.40 (0.99–1.97)
Migraine	105 (7%)	77 (7%)	0.88 (0.64–1.21)
Epilepsy	7 (1%)	6 (1%)	0.75(0.25–2.30)
Cancer (including leukaemia)	30 (2%)	20 (2%)	0.87 (0.45–1.58)
Ulcer (stomach or peptic)	91 (6%)	72 (7%)	0.83 (0.59–1.17)
Dermatitis	145 (9%)	95 (9%)	1.08 (0.81–4.43)
Eczema or hayfever	237 (15%)	152 (15%)	1.01 (0.80–1.27)
Chronic bronchitis or other lung disease	59 (4%)	41 (4%)	1.01 (0.65–1.55)
Diabetes	19 (1%)	13 (1%)	0.93 (0.44–2.00)
Depression or anxiety	140 (9%)	96 (9%)	0.95 (0.71–1.27)
Heart attack or disease	31 (2%)	27 (3%)	0.75 (0.43–1.33)
Vibration white finger	38 (3%)	25 (2%)	1.06 (0.61–1.83)
Receiving medical treatment	301 (20%)	242 (24%)	0.74 (0.60–0.91)

[a]Logistic regression model is adjusted for age, binge drinking, smoking (pack years) and BMI. In these models non-divers are the reference group.

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Table 3. Comparison of the prevalence of reported symptoms between divers and non-divers

	Subjects with the symptom *n* (%)		Adjusted OR's mean (95% CI)[a]
	Divers	Non-divers (reference)	
Forgetfulness or loss of concentration[b]	274 (18%)	60 (6%)	3.81 (2.73–5.31)
Musculoskeletal symptoms[c]	639 (41%)	352 (34%)	1.44 (1.21–1.72)
Hearing impairment	239 (16%)	113 (11%)	1.57 (1.21–2.04)
Skin rash or itch	101 (7%)	97 (9%)	0.66 (0.49–0.90)
Cough or wheeze	52 (3%)	54 (5%)	0.72 (0.47–1.10)
Breathlessness	52 (3%)	50 (5%)	0.75 (0.49–1.14)
Abdominal pain, diarrhoea, constipation or nausea	87 (6%)	46 (4%)	1.28 (0.87–1.88)
Muscle weakness or tremor	61 (4%)	33 (3%)	1.39 (0.88–2.20)
Unsteadiness when walking, dizziness and poor balance	26 (2%)	20 (2%)	1.15 (0.59–2.21)
Impaired vision (not corrected by spectacles)	54 (4%)	29 (3%)	1.46 (0.89–2.41)
No symptoms	529 (53%)	671 (45%)	0.67 (0.56–0.79)

[a]Logistic regression models adjusted for age, binge drinking, smoking (pack years) and BMI.

[b]Model also adjusted for educational attainment and head injury.

[c]Musculoskeletal symptoms include joint pain or muscle stiffness or neck or back pain.

Table 4. Indicators of morbidity between non-divers, NOSDs and divers working in the offshore industry

	Non-divers (*n* = 1030)	NOSDs (*n* = 234)	OSDs[a] (*n* = 874)
Employed	937 (91%)	231 (91%)	746 (85%)
Unemployed	36 (4%)	3 (1%)	69 (8%)
Retired	26 (2%)	12 (5%)	26 (3%)
Not working and on sickness benefit or retired due to ill-health	31 (3%)	6 (3%)	33 (4%)
Receiving medical treatment or medication	242 (23%)	50 (21%)	153 (17%)
Symptom tendency score, median (iqr)	3 (2–6)	3 (1–5)	5 (2–7)

[a]Seven participants were omitted because of missing data.

Results

Questionnaire return and exclusion data are shown in Figure 1. Of those responding, 66% of divers and 63% of non-divers responded to the first mailing. Twenty-four per cent of both groups responded to the second mailing and 10% of divers and 13% of non-divers to the third. Late responders did not differ from early responders in diagnosed medical conditions, HRQOL or symptoms. They did not differ in age, social deprivation or binge drinking but late responders were more likely to be a current smoker and have lower educational qualifications.

The prevalence of reported diagnosed medical conditions in divers and non-divers is shown in Table 2. Only two differences were found between divers and non-divers. Divers were less likely than the control group to report asthma or hypertension. There was no difference between the two groups in the number of diagnosed medical complaints reported per participant.

The prevalence in divers and non-divers of suffering symptoms is shown in Table 3. Divers were more likely to report suffering from 'forgetfulness or loss of concentration', musculoskeletal symptoms and 'hearing impairment'. Conversely, non-divers were more likely to report 'skin rash or itch'. Symptom tendency score was higher in divers (median 4, interquartile range 2–7) than in non-divers (median 3, interquartile range 2–6) ($P < 0.001$), and divers were more likely to suffer four or more symptoms (9% versus 6%. $P = 0.006$).

PCS of HRQOL did not differ between the divers and non-divers. The mean (SD, median) PCS for divers was 52.0 (7.9, 54.9) and 52.0 (7.6, 54.5) for non-divers [$F(1,2438) = 0.2$, $P = 0.7$]. The mean score for both groups was slightly higher than the population norm. The MCS for both groups was greater than the population norm and slightly higher in divers than in non-divers. The mean (SD, median) MCS for divers was 51.6 (9.1, 54.7) and 50.7 (9.4, 53.5) for non-divers [$F(1,2438) = 6.5$, $P = 0.01$]. Diagnoses and symptoms were associated with lower HRQOL scores in both groups. Depression was associated with a large effect size for MCS and arthritis and heart attack or disease with a large effect size for PCS. Other associations with diagnoses had a small to moderate effects size. Musculoskeletal symptoms and hearing complaint had a moderate effect size in association with reduced PCS and MCS. The symptom of forgetfulness or loss of concentration had a large

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Table 5. Logistic regression model comparing prevalence of symptoms and medical treatment in non-divers with NOSDs and divers in the offshore industry

	Subjects reporting the symptom (%) [adjusted OR (95% CI)][a]		
	Non-divers (reference)	NOSDs	OSDs
Forgetfulness or loss of concentration	6% (1.0)	9% [1.9 (1.1–3.3)]	22% [4.8 (3.4–6.8)]
Musculoskeletal symptoms	34% (1.0)	30% [0.9 (0.7–1.3)]	46% [1.6 (1.3–2.0)]
Impaired hearing	11% (1.0)	11% [1.0 (0.6–1.6)]	17% [1.7 (1.3–2.3)]
Moderate to severe complaint for four or more symptoms	5% (1.0)	5% [0.9 (0.5–1.8)]	10% [1.9 (1.3–2.7)]
Receiving medical treatment or medication	23% (1.0)	21% [0.8 (0.6–1.2)]	17% [0.6 (0.5–0.8)]

[a]Logistic regression models were adjusted for age, binge drinking, smoking (pack years) and BMI (forgetfulness was also adjusted for educational attainment and head injury).

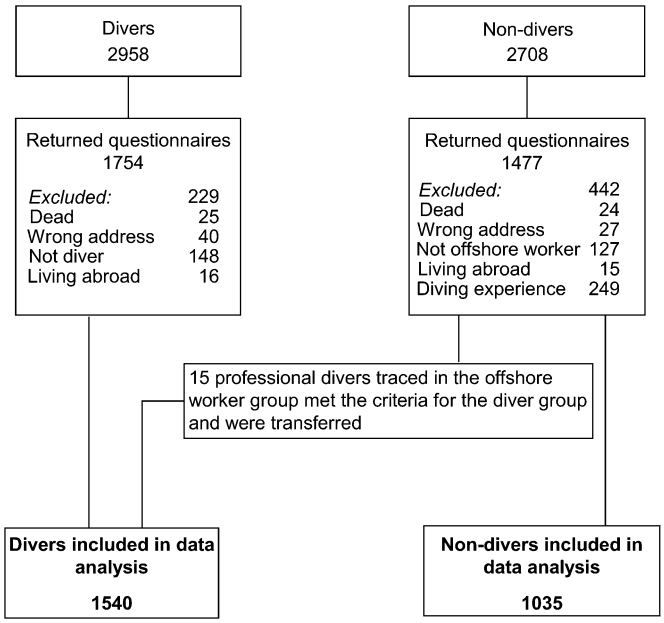

Figure 1. Response to the questionnaire with those who were excluded from the analysis (the numbers refer to the number of people). Five per cent (n = 148) of the traced divers did not complete the questionnaire since, despite having gained a professional HSE diving certificate, they had never worked as a professional diver. Similarly, 5% (n = 127) of the comparison group did not complete the questionnaire, reporting that they had not worked offshore despite having had an offshore medical examination. Offshore workers who reported having dived recreationally (n = 233) or professionally (n = 16) were excluded from the comparison group. Fifteen of the offshore workers who had worked as a professional diver met the criteria for the diving group and were therefore transferred into this group.

effect size in association with both reduced MCS and PCS in non-divers while it was moderate in divers.

Only 3% of the whole study population was not working because of illness or disability and the prevalence of reported disability was the same for OSDs, NOSDs and non-divers (Table 4). OSDs were more likely to report being unemployed than non-divers (OR 2.4, 95% CI 1.6–3.6) while other divers were not (OR 0.4, 95% CI 0.1–1.2). OSDs were less likely to report receiving medical treatment while there was no difference in reporting this between the other two groups (Tables 4 and 5). There was no difference in the prevalence of any diagnosed medical condition between OSDs and NOSDs and no difference in the number of diagnoses per participant.

Prevalence of 'forgetfulness or loss of concentration' was higher in NOSDs than in non-divers, but was higher again in OSDs. Musculoskeletal and hearing symptoms were commoner in OSDs than in either of the other two groups but there was no difference between non-divers and NOSDs (Table 5).

Symptom tendency score was higher in OSDs (median 5, iqr 2–7) than in either non-divers (median 3, iqr 2–6, $P = 0.009$) or in NOSDs (median 3, iqr 1–5, $P < 0.001$) and OSDs were more likely to report four or more symptoms (Table 5).

Discussion

This study shows that there are health-related differences between men with professional diving experience and men who have never dived. The lower incidence of asthma and hypertension is likely to be due to health screening differences between the two groups. Although recent attitudes have been more tolerant towards stable asthma and hypertension in divers, these two conditions tended to be screened out of the diving workforce prior to 1991.

Divers were more likely to report symptoms and had a higher prevalence of cognitive, musculoskeletal and hearing complaints. Multiple symptom reporting can be a feature of a somatizing disorder and symptom scoring systems are useful in screening for somatization [11,15,16]. A somatizing disorder can be defined as illness characterized by symptoms of physical disease with no underlying corresponding physical pathology. However, although a symptom tendency score was higher in OSDs, it was low in all the groups. Alcohol abuse and a diagnosis of anxiety and depression, which are associated with somatizing disorder [17,18], did not differ between groups. Further, divers less frequently reported medical treatment and had a slightly higher

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MCS. Divers, however, may have a greater perception that cognitive, musculoskeletal and hearing problems are associated with their profession. Cognitive dysfunction and neurological disorder in association with diving have been studied by research groups in Norway [7,8] and this has been publicized in relation to compensation claims in that country. Decompression illness is a major occupational risk for divers and musculoskeletal pain and neurological disorder are its principle manifestations. Dysbaric bone necrosis is another occupational risk in divers and it presents as arthritis of the shoulders and hips. Ear infection is commoner in divers and there is a prominent risk of sinus and otic barotraumas. Sound is more effectively conducted in water than in air with increased risk of noise-induced hearing loss. Awareness of these occupational risks is promoted during diver training. While a greater perception of these issues might have led to more frequent symptom reporting by divers, there is no supporting evidence from the present study that this amounted to the illness of a somatizing disorder.

Symptom reporting may be evidence of an underlying physical disorder. Cognitive complaint was commoner in both OSDs and NOSDs although OSDs were more affected. It was commoner, therefore, in a group of divers (NOSDs) who did not show any increased tendency to report multiple symptoms. This supports the concept that the symptom is not entirely psychosomatic. Further, in a random sample selected from respondents from this study, we have found that the symptom was associated with poorer memory performance in objective neuropsychological testing [19] and reduced grey matter volume in brain areas associated with memory function in a preliminary magnetic resonance imaging analysis [20]. These differences, however, did not amount to abnormality.

Musculoskeletal disorder has been associated with diving by other workers both with and without an association with decompression illness [1,2,21]. However, since diagnosed arthritis was no commoner in divers in the present study and somatizing is important in assessing musculoskeletal symptomatology [22,23], this aspect needs confirmation by physical examination.

Similar considerations apply to the higher prevalence of hearing complaints in divers. Subjective auditory symptoms may correlate with noise exposure and objectively determined hearing loss [24,25] and populations of divers have been identified as having a high prevalence of noise-induced hearing loss and to suffer a faster decline in hearing with age [26,27]. Complaint of hearing impairment, however, was related to multiple symptom reporting and objective examination is required before any conclusions can be reached.

Prevalence of reported ill-health disability in divers did not differ from controls in this study. Neither was there an effect associated with diving in the offshore oil and gas industry. Indeed, fewer OSDs reported receiving medical treatment than non-divers. Although OSDs were more likely to report unemployment, this is attributable to their pattern of employment since they are usually hired on short-term contracts and, between contracts, the diver may be unemployed but without any underlying health problem. The situation would seem to differ from observations made on Norwegian divers working in the North Sea industry at about the same time as the UK divers in this study [9]. The perception of diving as a cause of illness seems to have been higher in Norway than in the UK and this is evidenced by the Government-funded compensation scheme in that country. It may be that there are psychosocial pressures on Norwegian divers that are absent in the UK. The availability of compensation for injury has been associated with marked psychosocial effects on health status [28,29]. Also, differing perceptions of the significance of injury or likelihood of illness can be responsible for national differences in health status [30–33]. Recognition of a psychosocial element in disability related to a diving career has important implications regarding future interventions in the international diving workforce. If interventions introduce the concept of disorder to a naive workforce, the disorder may then manifest in a hitherto problem-free population [34].

The study has weaknesses and strengths. Unavoidable weaknesses lie in the subjective nature of questionnaire returns and the cross-sectional nature of the study with the assumption that the two groups were alike at the start of their careers. To start work, however, both groups would have had to pass a medical examination of fitness to work [35,36]. This has differed importantly only in the requirement for pulmonary spirometry and a physical fitness test for divers. Subsequent examinations are annually for divers and three yearly to annually dependent upon age for offshore workers. At the start of their career, therefore, the groups may have differed in physical fitness but would have been of similar health status. Certainly, at the time of this study, there was little difference between the two groups in this regard.

The major strength of the study was the method of subject selection. Possible subjects were identified objectively and did not volunteer to receive a questionnaire so minimizing self-selection bias. Basing the inclusion criteria on employment 10 years before the study began, minimized healthy worker effects and survivor bias. Healthy worker effects were also reduced by choosing a control group from another equivalent industry, but without exposure to diving. Finally, the use of repeated reminder questionnaires established that the sample represented the underlying population.

In summary, UK divers working prior to 1991 were less likely to report diagnoses of hypertension or asthma but were more likely to report symptoms and reported 'forgetfulness and loss of concentration', hearing impairment and musculoskeletal symptoms more frequently than controls. Although there may be a basis for cognitive complaint in this group from other studies, the validity of

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hearing and musculoskeletal complaints remains to be proven. In contrast with a high level of disability in Norwegian divers active in the offshore oil industry at the same time, UK offshore oilfield divers showed no such evidence and reported receiving less medical treatment than controls. Since the industrial exposure undergone by these two groups is likely to have been similar, psychosocial factors may underlie the differences between them.

Key points

- Divers had a similar HRQOL to non-divers and were no more likely to report ill-health-related disability but offshore oilfield divers showed some evidence of a somatizing tendency. This supports the concept that psychosocial factors underlie the difference in prevalence of disability between Norwegian and UK divers working in the oil industry prior to 1991.
- The interpretation of the health effects of diving and the planning of any future health-related interventions in this workforce should allow for psychosocial factors.
- Divers were more likely than non-divers to report cognitive symptoms and the underlying cause for this remains to be defined.

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Conflicts of interest

None declared.

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