An evidence-based system for health surveillance of occupational divers

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Abstract

Background: The value of the commonly required routine annual medical examination of occupational divers has been questioned, and there is a need for a robust, evidence-based system of health surveillance for this group of workers.
Aims: To determine whether the medical examination and investigation component of occupational divers' routine comprehensive health surveillance adds significantly to the information gained from the questionnaire component in determining fitness for diving.
Methods: An occupational diver database was interrogated to identify divers issued with a 'limited' medical clearance or considered 'unfit' for diving over a 5-year period. Reasons for the 'unfit' or 'limited' designation and the source of the critical information, whether the annual health questionnaire or the medical examination or questionnaire component (or both) of the initial or 5-yearly comprehensive medical evaluation, was recorded. For divers completing the 5-yearly repeat comprehensive medical evaluation, the sensitivity and specificity of the questionnaire alone for determining unfitness for diving was compared with that of a nominal 'gold standard'.
Results: Of 5178 certificates issued to 2187 divers over a 5-year period, 158 (3%) were provisionally designated as either 'limited' or 'unfit'. Of nine divers identified by the examination component of the 5-yearly comprehensive medical evaluation, four were eventually designated 'fit', two 'limited', and three were lost to follow up. None who had completed subsequent investigations remained 'unfit'. The sensitivity and specificity of the questionnaire to detect unfit divers compared with the gold standard were 84.6 and 99.3%, respectively, and its accuracy was 98.9%.
Conclusion: The current New Zealand occupational diver medical certification process, comprising annual health questionnaires and 5-yearly full examinations, detects all health issues critical to the determination of fitness to dive.

Introduction

Most occupational divers worldwide are required to undergo an annual comprehensive medical examination. The widely accepted but unproven rationale is that comprehensive health surveillance should reduce occupational morbidity and mortality. Industry standards and guidelines exist to assist examining medical practitioners in the determination of fitness for diving.[1–4] These include examples of medical conditions that could render the diver unfit, or fit for diving, but with certain limitations.

One country where the requirement for annual comprehensive medical examination does not apply is New Zealand, where a 2002 analysis of 300 occupational diving medical assessments cast doubt on the value of comprehensive medical evaluations and prompted the institution of a system requiring such evaluations only 5-yearly, with the completion of a health screening questionnaire in the intervening years.[5] We previously audited the first 336 divers completing a 5-year cycle under this system and demonstrated that the annual health questionnaire detected all significant health problems arising after the initial comprehensive medical, with the 5-yearly full medical examination adding little value.[6]

The aim of the current study was to revalidate or refute the latter finding in a larger and more

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contemporary cohort of occupational divers whose health status has been monitored under the New Zealand system.

Methods

This study was approved by the Waitemata District Health Board Human Ethics Committee (reference number RM13088). All divers whose records were accessed had consented to their anonymised occupational medical information being used for research purposes. The New Zealand occupational diver medical database was interrogated to identify all divers issued with a 'limited or conditional' medical clearance or considered 'unfit' for diving over a 5-year period, from the beginning of 2010 to the end of 2014. When a diver was designated 'limited' or 'unfit', we recorded the reasons for this designation identified from the divers' individual records and the source of the information leading to application of those designations, whether from the questionnaire alone or the examination component of the initial or 5-yearly comprehensive medicals or from the annual questionnaires. To be clear, we include any findings from discussions or system reviews in the definition of the 'examination component' of the comprehensive medicals.

As the focus of this study is on the adequacy of the health surveillance of occupational divers, we limited our analysis to experienced divers who had previously undergone an initial comprehensive dive medical examination followed by four annual health questionnaires. We therefore defined the 'gold standard' for the determination of diving fitness as the combination of the questionnaire plus the 'subsequent' medical examination and any investigations that were indicated. The primary outcome measure was a calculation of the sensitivity and specificity of the questionnaire alone in detecting problems leading to a designation of unfit or limited, in comparison with this gold standard. Statistical analysis used a web-based Bayesian calculator for the exact 95% confidence limits of a proportion (or credible interval) to define the sensitivity, specificity and accuracy of the questionnaire compared with the gold standard. The accuracy of the questionnaire in determining 'unfitness' or 'limited fitness' to dive was calculated by dividing the sum of true positive and true negative outcomes by the total sample number. We defined a 'positive' finding as a finding of unfit, limited or lost to follow up. The latter group was included as a conservative assumption for sensitivity calculations only because of the possibility of unfitness. As a secondary outcome, we recorded the source of the critical information and the nature and incidence of various health conditions leading to the provisional 'limited' or 'unfit' designation.

Results

Within the entire programme (initial comprehensive medicals, annual questionnaires, 5-yearly repeat comprehensive medicals), 5178 certificates were issued over 5 years, representing 2187 active occupational divers, of which about 1000 apply or re-apply each year. The age distribution of these divers is presented in Figure 1. The mean age of all divers was 39 years (range: 18–68). The sources of key information leading to the designation of a diver as unfit or limited are summarised in Figure 2

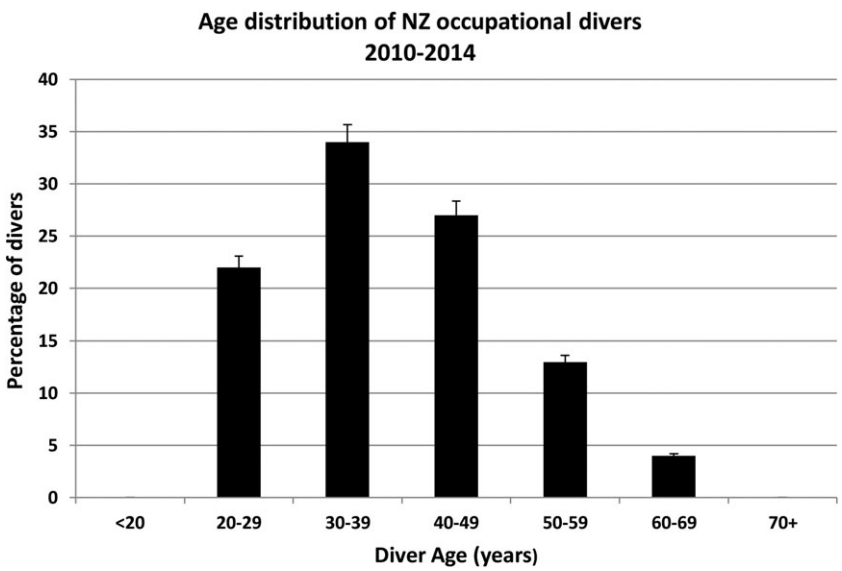

Figure 1 Age distribution of New Zealand occupational divers 2010–2014.

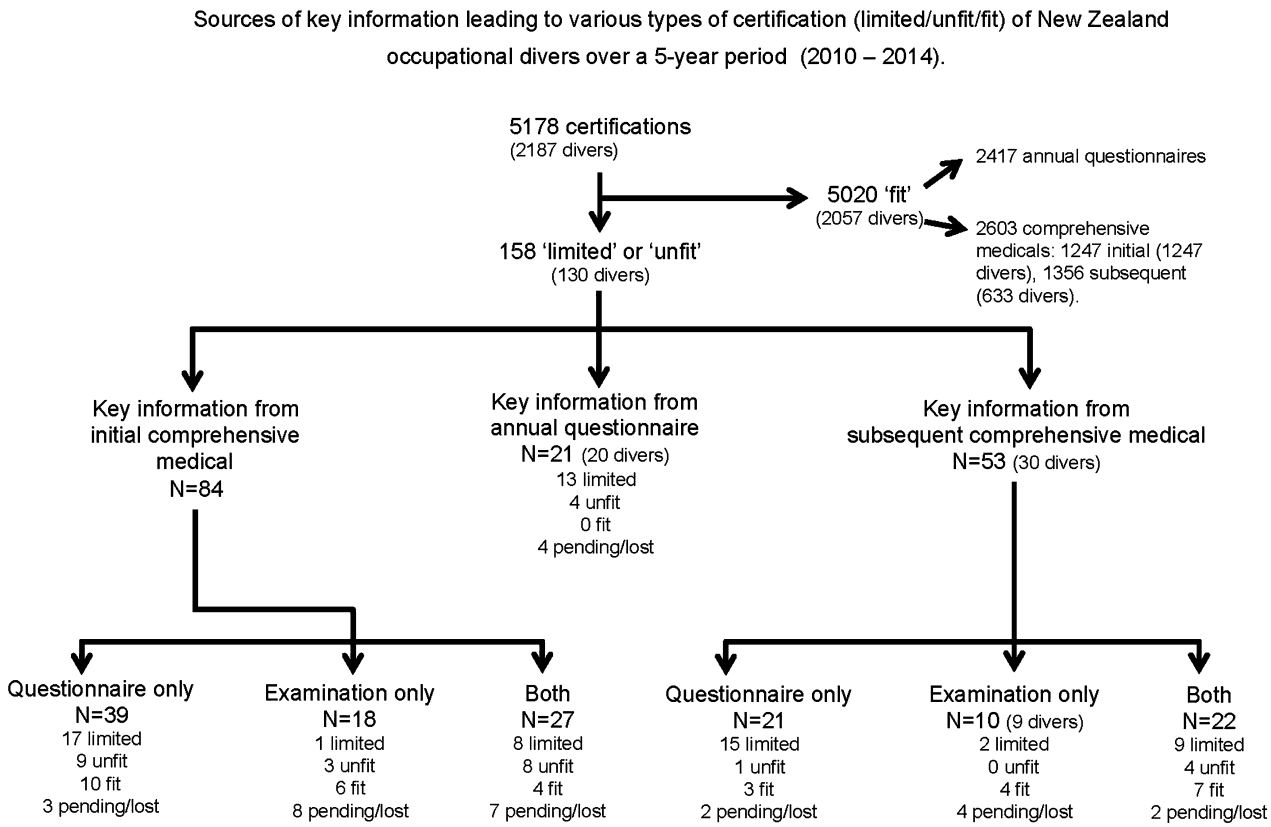

Figure 2 Sources of key information leading to various types of certification (limited/unfit/fit) of New Zealand occupational divers over a 5-year period (2010–2014). Key information on which the designation of 'fit', 'limited' or 'unfit' was based came from either the questionnaire component alone, the examination component alone or from both the questionnaire and examination. In those comprehensive medical scenarios where key information is denoted as arising from 'both' the questionnaire and examination, it is implied that the initial identification of a potential problem was detected by the questionnaire.

and stratified by diagnosis in Table 1. The bottom four lines of Figure 2 represent the gold standard findings. The 158 unfit or limited certifications represented 130 divers (21 were represented more than once), of whom 29 were females, and whose mean age was 37 years (range: 18–65). In 28 of these certifications (17.8%), the critical information leading to a limited or unfit designation was revealed by medical examinations alone, 18 (64%) of which were at the initial compulsory medical examination. In contrast, in 130 of the 158 (82.2%) limited or unfit certifications, critical information was revealed by the questionnaire.

Nine of 663 divers (1.4%) who completed a 4-year cycle in which no important problems were detected by the annual questionnaire were provisionally designated as either limited or unfit based only on the examination component of the subsequent full medical examination. Of these, three were lost to follow up, and four were designated 'fit' and two 'limited' (none 'unfit') after further investigations. The two 'limited' had abnormal lung function tests but then passed a saline challenge test and were designated 'limited' only because of a requirement for annual saline challenge tests. The three lost to follow up represented four certifications because one of them presented for a full medical examination twice in consecutive years but was lost to follow up both times after failing to complete the recommended investigation. Two were obese and were asked to perform an exercise electrocardiogram, and the other had an abnormal lung function test and was asked to submit to a hypertonic saline challenge test. Even counting these three divers as 'unfit', the unfitness detection rate for the examination component of the 5-yearly comprehensive medical was 4 out of 1409 (0.28%) certifications or 3 out of 663 (0.45%) individual divers.

In comparison with the gold standard, the sensitivity and specificity estimates of the questionnaire to detect unfit divers were 84.6% (confidence limit

Table 1 Incidence and source of diagnoses leading to the provisional designation of 130 New Zealand occupational divers as unfit/limited over the 5-year period 2010–2014

Diagnosis	Questionnaire (Q)	Medical examination (M)	Both Q + M	Total
Asthma	18	4	22	44
Abnormal LFT		13	9	22
Obesity		11	8	19
Chamber attenedant	14			14
Hearing deficit	5	1	8	14
Psychiatric illness	13		1	14
Arrhythmia	5		3	8
Hypertension	2	3	2	7
Blood disorder	7			7
Hx pneumothorax	1		2	3
Colostomy	1		2	3
Bronchiectasis	2			2
Ankylosing spondylitis	1		1	2
Hx DVT/PE	1		1	2
Recent hx DCS	2			2
Fibromyalgia	2			2
Psoriatic arthritis	2			2
Epilepsy	2			2
Tinnitus			1	1
Valvular defect			1	1
CAD			1	1
Hx chest pain	1			1
PFO	1			1
Recent IEBt	1			1
Migraine	1			1
Post-concussion syndrome			1	1
Recent retinal surgery	1			1
Thrombocytopenia/ SLE	1			1
Thyrotoxicosis	1			1
Recent head injury	1			1

CAD, coronary artery disease; DCS, decompression sickness; DVT, deep vein thrombosis; Hx, history; IEBt, inner ear barotrauma; LFT, lung function test; PE, pulmonary embolism; PFO, patent foramen ovale; SLE, systemic lupus erythematosis.

(CL) = 70.2–92.7%) and 99.3% (CL = 98.7–99.6%) respectively. This could mean that up to two potentially unfit divers per year were missed by the questionnaire. The width of the confidence interval for the sensitivity suggests that this study was underpowered, but the sensitivity estimate is conservative based on the inclusion of two divers who were actually fit to dive but required annual respiratory review and three whose fitness-to-dive is unknown. As mentioned above, none of these divers was definitively unfit. The accuracy of the questionnaire was 98.9% (CL = 98.16–99.30%).

The estimates of sensitivity and specificity were based on figures for true and false positives and negatives derived from the data shown in Figure 2. The derivation of the values for true positives (33), true negatives (1360), false positives (10) and false negatives (6) is demonstrated in Figure 3. These numbers refer to the number of certifications, not divers. To clarify, using the 'gold standard' as defined above and the focus on the subsequent comprehensive medicals, the values in Figure 3 were reached by following the right branch of Figure 2. It is implicit that a finding of unfit by 'examination only' means the questionnaire finding was 'fit'. So, for example, to derive the figure for true positives, we added the gold standard findings where the questionnaire also found divers to be unfit (1 + 4), limited (15 + 9) or lost (2 + 2), giving a total of 33. For the true negatives, we added the 1356 designated 'fit' at the first step (of the 5020 found 'fit' by both examination and questionnaire) to the four under the 'examination only' heading found fit by the gold standard because these were also found fit by the questionnaire, giving a total of 1360.

The most common positive responses to the questionnaire were to the questions on current medication (38%), previous chest X-rays, audiograms, spirometry or hypertonic saline challenge tests (33%), history of asthma (28%) and past hospitalisation (21%).

Discussion

Our data demonstrate that important health information relating to fitness for occupational diving are much more likely to be revealed by a screening questionnaire than by examination or investigations conducted as part of a comprehensive medical evaluation. Moreover, the majority of any positive examination/investigation findings are made at the initial compulsory comprehensive medical evaluation rather than at subsequent or 5-yearly evaluations. Only 9 of 663 divers who completed an initial comprehensive medical and a 4-year intervening period of negative responses to a screening questionnaire had significant problems detected by a subsequent examination, and none of the six who completed further investigations was eventually found to be unfit. The assumption of a worst case ('unfit') designation for the remaining three divers who were lost to follow up resulted in an 'unfitness' detection rate of 0.45% (excluding those with 'limited' fitness) for the examination component of the 5-yearly comprehensive medical evaluation. This represents the contribution to unfitness detection made from adding the examination and investigations to the questionnaire at the 5-yearly comprehensive medical stage.

		Gold Standard		
		Unfit/Limited/Lost (P)	Fit (N)	
Questionnaire	Unfit/Limited/Lost (P)	(15+9)+(1+4)+(2+2) = 33 (TP)	3+7 = 10 (FP)	43
	Fit (N)	2+0+4 = 6 (FN)	1356+4 = 1360 (TN)	1366
		39	1370	1409

Figure 3 Derivation of true and false positives and negatives. True and false positives (TP, FP) and true and false negatives (TN, FN) were derived from the data shown in the Figure 2 flowchart following the right branch that relates to subsequent comprehensive medicals. Numbers represent certifications not individual divers. The 'gold standard' refers to the completion of a questionnaire and the 'subsequent comprehensive medical' plus further investigations as indicated.

This study corroborates the findings of our previous investigation, which demonstrated that no important medical problems undetected by the annual questionnaire were subsequently detected by the examination component of the 5-yearly comprehensive medical in 336 divers who completed a 5-year cycle under that system.[6] This study audited all certifications over a 5-year period, whereas the previous study followed a cohort of 336 occupational divers who completed two comprehensive medicals, and the intervening annual questionnaires, over the same time frame. The advantage of auditing all certifications is that it captures the divers who 'fall at the first hurdle' and can deduce the health reasons and method of detection.

These results provide an evidence base for challenging the 'traditional' insistence on a comprehensive annual medical evaluation for all occupational divers. In particular, there appear strong grounds for claiming that after completion of a comprehensive medical evaluation on entry to the industry, ongoing health surveillance can be adequately achieved by annual completion of a well-designed screening questionnaire, with further comprehensive evaluations at greater than annual intervals (in our case, every 5 years). In our setting, such a system has not resulted in important medical problems being overlooked, and considerable money has been saved by avoidance of expensive comprehensive consultations and repetitive investigations. The reasons for regulating authorities adhering to the tradition of an annual comprehensive medical evaluation in the face of evidence that there is no corresponding health benefit for divers are unknown.

The value of routine, annual, comprehensive physical evaluations in the context of an asymptomatic general population has been questioned, apart from a small number of components (such as blood pressure, weight, Pap smears) whose regular monitoring may result in improved health outcomes.[7] However, such evaluations (the 'yearly physical') remain popular with both the general public and with physicians, who cite benefits like reduction of patient anxiety, strengthening of the doctor–patient relationship and the sense of caring and forestalling possible medico-legal complaints.[8–10] In the context of routine occupational health assessments, it is likely that many employers take legal, rather than evidence-based, medical advice regarding the frequency and comprehensiveness of physical examinations, but they may also be persuaded by these other putative benefits.

Divers, like many other occupational groups, face specific, job-related health risks, and although pre-existing health conditions can contribute, most of the risk is derived from a combination of factors, such as accidents, equipment failure, inexperience or adverse environmental conditions, rather than health status alone.[11–13] However, if risk mitigation is possible through periodic health assessments, regulating authorities and/or employers are obliged to ensure that the nature and frequency of such assessments are based on evidence.

Studies of questionnaire-based health assessments of recreational divers in Scotland have demonstrated virtually invariable detection of divers whose health required further investigation.[14,15] A study of recreational diving in Australia challenged these findings by reporting 9 of 632 diver candidates answering in the negative to all questions on a screening questionnaire who subsequently failed a face-to-face medical.[16] The reasons for some of these failures were open to debate (such as failure to meet arbitrary spirometry standards), and it can be argued that such problems are more likely in a more comorbid recreational population whose mean age is considerably higher than the occupation cohort reported here.[17] In the occupational setting, our previous audit of 336 New Zealand occupational divers over a 5-year period and the data presented here support the Scottish findings.[6]

This study has several limitations that must be acknowledged.

First, the questionnaire used for the annual health surveys is not the standard document designed for use in comprehensive occupational diver medicals in Australia and New Zealand. It is a more comprehensive questionnaire that focuses on enquiry about symptoms as much as diagnoses, and it went through a substantial development phase in which we adjusted it to improve utility and comprehension during informal trials with divers. Its use would be generalisable, but the fact that it is not a standard questionnaire needs to be acknowledged.

Second, New Zealand has a system of central arbitration in which all returned questionnaires and completed comprehensive evaluations are viewed, and certifications are issued by a primary reviewer supported by a secondary expert panel. This may enhance the efficacy of questionnaires as tools for health surveillance because individual divers become known and can be tracked although they may interact with different doctors in the community. This system also provides consistency in the evaluation of divers' fitness and mitigates the inconsistency found in the diving fitness decisions of doctors in both New Zealand and Australia.[18,19] Although we believe a questionnaire system would still work if administered locally by individual doctors, the circumstances of the study do raise a possible limitation of the generalisability of our findings in those jurisdictions where it may not be practicable to develop a diver certification system that includes central evaluation.

Third, the low incidence of 'unfitness' in this cohort, likely to be a 'healthy worker' effect, resulted in the study appearing to be underpowered. We would expect a higher incidence of unfitness if we included divers attending their initial comprehensive medical, but we focused on the more experienced divers for this study, acknowledging that there is a pre-selection bias. To achieve the same sensitivity (85%) for the questionnaire to detect unfit divers, in comparison with the gold standard, with 95% confidence but narrower confidence limits of say 80–90%, would have required a sample size five times as large as our study cohort. In the New Zealand setting, this would require data collection over 25 years, and this is not currently feasible.

Finally, our results and conclusions could be challenged on the basis of value judgements about whether the cost and logistic savings from not requiring frequent comprehensive medical examinations outweigh the potential harm from a diver being incorrectly certified as healthy. Our response to such criticism would be twofold. First, not a single diver in our study was definitively found to be unfit based on information obtained solely from the examination component of the follow up comprehensive medical. We have assumed that the three divers who did not complete follow up (see above) were unfit for the purposes of analysis, but this is a deliberately conservative assumption. Second, while we acknowledge that insistence on annual comprehensive medicals can only lower the risk of an adverse event, we believe that the principle of not pursuing costly interventions with very low yield just because there is a small chance of benefit is well established in medicine. A detailed cost-benefit analysis of our results is beyond the scope of this study but is a probable topic for future consideration.

Conclusion

After the initial comprehensive medical evaluation, health issues leading to occupational divers being considered 'unfit' were discovered almost exclusively from an annual online health questionnaire. A routine 5-yearly comprehensive medical examination provided little or no extra critical information. Apart from their perceived 'intangible' benefits, costly annual comprehensive medical examinations are difficult to justify for occupational divers.

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