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**HSE Workshop on Exercise Testing For Divers  
Monday the 19th April 2004**

**HSL/2004/10**

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**Science Group:** Health Sciences

## **Acknowledgements**

The authors would like to acknowledge the advice of Dr Nerys Williams (EMAS HSE) for advice during the organisation of the meetings and to Ms Tina Chester for the transcription of the meeting and to Dr Shamim Rahman (HSL) for collating information from the participants.

## EXECUTIVE SUMMARY

**OBJECTIVES:** This meeting was organised in response to concerns that were raised by Dr Stephen Glen (Consultant Cardiologist, Stirling Royal Infirmary) and Dr Peter Wilmhurst (Consultant Cardiologist, Royal Shrewsbury Hospital) at the Sports Diving Medical Committee Diving Conference November 2003. These concerns were about the risk to health when divers undergo exercise tests during their medical examination. There are approximately 5,000 HSE approved diving medicals carried out each year and there is concern that for some individuals (particularly males older than 45 years of age) the exercise test regime may increase the risk of a fatal cardiovascular event. The meeting included representatives from HSE (and the HSE Diving & Offshore Policy Unit), experienced AMEDS and cardiologists as well as representatives from the diving industry and training organisations. The objective for this meeting was to review the current medical examination, and to make recommendations to HSE for improvements to the medical examination if changes were needed.

**MAIN FINDINGS:** Apart from the 5000 HSE approved diving medicals there are ~3,000-4,000 recreational instructors ('at work') who train ~40,000 members of the public every year, in addition to this number the Armed Forces employ 1,500 divers. Despite these numbers and the occurrence of few reported cases of myocardial infarction the true scale cardiovascular events amongst divers undertaking 'step testing' exercises was not known.

However, there was consensus that significant variation existed between AMED's in the way that they carry out and interpret the results of exercise tests for the diving medical. Some apply a screening health questionnaire to assess the medical history prior to the exercise testing. Some practitioners use ECG at the end of the step testing whilst others monitor pulse rate throughout. Different standards of the exercise testing may also be applied to determine aerobic capacity vs cardiovascular fitness (stress testing) particularly in the hospital setting where a trained Cardiologist may be present.

The step exercise protocol is commonly used to assess levels of fitness for the diving medical and the purpose of this test is to measure aerobic capacity and cardiopulmonary response but not to detect underlying ischaemic heart disease. The test is not useful for screening for diving induced pulmonary oedema because of its low sensitivity and the need for continuous blood pressure monitoring. There is a distinction between assessing fitness e.g., step tests, and assessing fitness for specific work activity e.g., an unforeseen rescue situation. Generally the fitness requirements to deal with specific tasks were not easy for the AMED to quantify. Furthermore the employer is responsible for this when carrying out a risk assessment of the work.

It was suggested that an age cut off could be applied to those undergoing the exercise testing. Evidence collected by the American College of Cardiologists suggests that for males over the age of 45 year (and for women over the age of 55) there is a significant increase in the risk of ischaemic heart disease and myocardial infarction. Airline pilots undergo routine health surveillance and this takes into account the influence of age, family history of heart disease, raised cholesterol, and diabetes. However, it was emphasised that there is no substantial evidence of elevated risk for cardiac disease amongst working divers over such age limits. Furthermore, specific cardiac stress testing protocols can still miss a significant proportion (~10%) of younger people with single vessel disease and these tests are more suited for those with triple vessel disease.

It was concluded that no single 'ideal' exercise test exists which can measure aerobic and physical demands of diving including all mixtures of work (diving, equipment configuration,

gas mixtures and emergencies). All of the current testing protocols have limitations and exercise testing is only a surrogate for job specific fitness.

The need for the exercise testing to be carried out at centres equipped for cardiac resuscitation by experienced medical staff was discussed. Should an individual suffer myocardial infarction during testing it would be better if this occurred at a facility with appropriate equipment and staff present. However, these requirements would escalate the cost of the AMED medical and many self-employed divers would be unable to afford this even if it were only applied above a certain age threshold age. Whilst there are inconsistencies in the current testing regime withdrawing it from the medical examination was not considered an option since the test was regarded as a valuable health promotion tool encouraging appropriate standards of physical fitness amongst divers. Step tests were to be preferred over other tests (bicycle ergometer) for their simplicity, cost, convenience, and because they are adequate for purpose.

### **RECOMMENDATIONS:**

- To examine ways to make the first medical examination that a new diver receives more in depth in order to establish prior risk factors for heart disease.
- To examine the value of pre medical screening questionnaires that could either be self-completed, completed by the diver in conjunction with their GP, or which could be sent to the GP prior to the divers medical examination. If the latter method was to be chosen the cost and practicalities of the scheme would have to be assessed.
- For a working party to be established to develop valid cardiac screening questionnaires based upon the DVLA model for heavy goods vehicles drivers.
- To examine whether it is practical to introduce an age 'cut off' (45 for males and 55 for females) beyond which the increased risk of cardiovascular disease will require the AMED to conduct a thorough medical screen before conducting any exercise testing.
- To assess the requirement for exercise testing to be carried out only if appropriate resuscitation equipment and adequately trained individuals are present.
- To consider whether markers of increased cardiovascular disease risk such as blood glucose, cholesterol and homocysteine should be used as part of the risk assessment for exercise testing males over the age 45.
- For HSE to consider a 'cost benefit' analysis to determine the acceptable risk for introducing additional exercise tests such as using the Bruce protocol stress test for screening purposes.
- For HSE to improve the data that is held on incidents of ill health associated with exercise tests for divers.
- For HSE to improve communication with employers about their responsibility to undertake appropriate risk assessments of work tasks; and improve communication with divers about their responsibility to remain physically fit.

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## 1.0 INTRODUCTION

The current version of the medical examination and assessment of divers (MA1) was last updated in 1998. The document outlines HSE's medical standards for diving at work. These standards are used by HSE approved Medical Examiners of Divers (AMED) to perform statutory medical examinations and assessments under the Diving at Work Regulations 1997. The standards are based on the physical requirements of diving work and the physiological consequences of such work.

Under the Diving at Work Regulations 1997 all divers at work must have a valid certificate of medical fitness to dive issued by the AMED.

In January 2004, work commenced on updating MA1 in view of changes in medical knowledge and thinking. Relevant Diving Medical Specialists agreed to update the various sections of MA1 but safety and validity issues concerning exercise testing were considered more complex (see Executive summary) and so a workshop to discuss these issues was proposed. The workshop included a wide range of diving medical specialists, AMEDs and Diving Physiologists who considered the current MA1 recommendations in light of concerns about safety as described. In addition, there was uncertainty about the relevance and validity of our current approach to exercise testing of divers where MA1 allows for a wide range of different testing techniques and protocols to be used.

Common to all commercial divers is the potentially strenuous nature of diving. A commercial diver must be able to meet the physical requirements of the task to be performed. This includes the ability to rescue a stricken diver and to affect a rapid recovery. It is for this reason that an assessment of exercise capacity is carried out at both the initial and subsequent annual assessment. The AMED must be satisfied beyond reasonable doubt that the candidate is fit. Accepting the limitations, HSE has approved an assessment of maximum oxygen uptake (whether direct or indirect) as a suitable marker of such fitness. The results of the exercise testing need to be considered together with other aspects of the assessment such as blood pressure, body mass index (BMI) and lung function.

In addition to exercise testing with its assessment of maximum oxygen uptake, the function of the diver's cardiovascular system should be such that the diver is able to sustain strenuous muscle activity at depth. There should not be an increased risk of loss of consciousness or incapacitation. Symptomatic heart disease, abnormal cardiovascular findings or a history suggestive of organic heart disease is likely to lead to rejection and all such cases should be discussed with, or referred to, a consultant cardiologist for specialist evaluation taking into account all relevant clinical findings.

The Exercise Workshop was therefore commissioned to review the safety of occupational exercise testing of commercial divers, to find consensus among appropriate specialists concerning the validity of these tests, to review the evidence base for current practice and to provide guidance on future testing regimes.

## **1.1 Agenda For Meeting**

**HSE Workshop on Exercise Testing For Divers  
Monday the 19th April 2004  
Radisson SAS Hotel, Manchester Airport.**

### **Agenda for meeting**

#### **Chairman's Remarks and Introductions.**

- HSE Diving Policy and Legal position: Mrs A. Darvill
- Commercial diving activities: Ms E. Little and Mr C. Sherman

#### **Session 1: Safety issues**

- Presentations: Dr Glen & Dr Vecht - Cardiovascular safety issues.
- General discussion
- Conclusions, areas of consensus \ disagreement \ uncertainty

#### **Session 2: Validity issues**

- Presentations: Mr G. Anthony & Mr K. George - Exercise physiology testing.
- General discussion
- Conclusions, areas of consensus, disagreements \ uncertainties

## 2.0 List Of Attendees

Dr David Snashall  
Head of Occupational Health Department,  
Guys and St Thomas' School of Medicine  
London

Dr John Challenor  
Head of Occupational Health  
Devon and Cornwall Constabulary  
Exeter

Dr Romeo Vecht  
Consultant Cardiologist,  
Royal Brompton Hospital  
London

Dr John King  
Occupational Physician  
Harley Street  
London

Dr Maggie Clamp  
GP & AMED  
Lowdham Medical Centre  
Nottingham

Dr Keith George  
Senior Lecturer (Exercise physiology)  
John Moores University  
Liverpool

Dr Gavin Anthony  
Principle Consultant (Diving & life support)  
QinetiQ  
Gosport

Mr Graham White  
Consultant (Exercise Physiologist)  
QinetiQ  
Gosport

Dr Mark Glover  
Surgeon Commander,  
Institute of Naval Medicine  
Gosport

Dr Gareth Evans  
Health Effects Section  
Health & Safety Laboratory,  
Sheffield

Ms Erika Little  
Health and Safety Advisor and Trainer  
Professional Association of Diving Instructors  
(PADI)  
Bristol

Dr Julian Smith  
Diving Medical Advisor  
HSE EMAS  
Manchester

Mr Chris Sherman  
HSE Chief Inspector of Diving  
Rose Court  
London

Dr John Broome  
Consultant Occupational Physician  
County Durham

Professor David Elliott  
Independent Consultant in Occupational  
Medicine (Diving)  
Haslemere  
Surrey

Dr Stephen Glen  
Consultant Cardiologist  
Stirling Royal Infirmary  
Sterling,

Dr James Douglas  
GP & AMED  
Tweeddale Surgery  
Fort William

Dr Peter Wilmhurst  
Consultant Cardiologist  
Royal Shrewsbury Hospital  
Shrewsbury

Mr Dominic Pritchard  
Solicitors Advisory And Drafting Unit HSE  
Rose Court  
London

Ms Anne Darvill  
Offshore Policy & Legislation  
Rose Court,  
London

## 3.0 SUMMARY OF PRESENTATIONS AND DISCUSSIONS

### 3.1 Policy and Practice

#### 3.1.1 Anne Darvill (HSE Policy Group):

Our role is to prepare briefings and speeches for HSC/ HSE and for ministers and we also ensure that the legislation is kept up to date. If problems occur we have to review the regulations and consult widely. The current 'Diving at Work Regulations' were issued in 1997 and following this we have issued further guidance including an 'Approved Code of Practice' (ACOP). The ACOP is a legal document and tells you exactly what has to be done to comply with the regulations. These documents deal with five categories of diving; offshore diving, media, recreational, scientific and archaeological as well as 'in-shore' diving.

When the 1997 regulations came out they partially relaxed the legal status and allowed for approval of examining doctors from overseas. However, this situation persisted for only a few years as it proved very difficult to audit the quality of the examinations, and there were other issues related to verification of the approved medical examiner of divers (AMED) system. From September 2001, the approval for overseas AMEDs was withdrawn as well as for AMEDs from European countries.

Under the EU Directive, which allows for freedom for movement of workers there are ongoing discussions to finalise an agreement with the member states, so that divers with appropriate medical certificates (issued by their approved doctors) will be accepted by UK diving contractors. This agreement only applies to Norway at present and it is hoped that the agreement will soon extend to Ireland, Netherlands and Sweden. These agreements are close to completion but there are some discrepancies, which need to be resolved.

With the new member states joining in May 2004 (that is another 10 countries) the possible way forward will be to agree to overseas medical certification based upon the European diving technology committee (EDTC) rules. It is to be hoped that this will be agreed by the other member states.

#### 3.1.2 Erika Little (PADI International Ltd, Bristol):

My focus is recreational and commercial instructors who teach. To illustrate the problems we deal with I will quote from a presentation given by Drew Richardson (Vice President PADI) that was delivered at the South Pacific Underwater Medicine Society in 1995 and then subsequently published in the June 1996 Edition of SPUMS Journal. This quotation illustrates the nature of the work for a typical PADI instructor.

*"Instructors of amateur recreational SCUBA divers are a distinct group with specialised systems and procedures. Generally this diving operation at work is categorised into three distinct areas:*

- 1. Performed solely for instruction, or educational purposes, or diving tours.*
- 2. Using open circuit compressed air SCUBA*
- 3. Conducted within the time and depth limits of 'no stage' decompression air diving (generally less than 30 m depth)*

*The working conditions of other groups of divers at work such as commercial divers differ widely from those of instructors of amateur recreational SCUBA divers and therefore are not comparable. The latter do not use surface supplied equipment or mixed gases, do not engage in diving requiring a staged decompression, bells or saturation techniques; do not use or handle construction tools, explosives, burning or welding equipment or perform under heavy work loads. They do not engage in situations exposed to adverse sea conditions or otherwise less than optimum working conditions. A SCUBA diving instructor may be an employee or an independent operator. He is student orientated, diver orientated and trainee orientated, not task orientated. The dive site is not generally determined by the location of a particular job as it is in commercial diving where operations must be conducted under environmental conditions that are often adverse. A SCUBA instructor by contrast selects a location, which is relatively shallow and conducive to training diving students. The instructor is free to use personal judgement and professional expertise in choosing a workplace free of recognised hazards in evaluating any natural or artificial body of water. They also have the ability to discontinue the dive at any point'*

This description should help you to understand the role of the PADI instructor and recreational instructor and this differs from other commercial instructors. With respect to what PADI instructors undertake during the course of training, this includes physical activities such as manual handling, diving profiles, exercises (including exertion, or ascent), and emergency procedures that are probably common to all divers. With respect to manual handling this involves single cylinders (10 and 12 litre cylinders) and the PADI instructor will be expected to lift these and place them into a vehicle and then remove them from the vehicle. They will occasionally (if teaching technical courses) use more than a single cylinder. Some of these will be to help students on with their kit; or to remove their kit; and this will be done from the water into a boat, or from a boat onto the shore. There is a certain amount of lifting and carrying of cylinders with this job. During a rescue diving course they also demonstrate lifts and how to lift someone from the water.

With respect to the dive profiles, as stated by Drew Richardson, these are dives without decompression and the majority are to a maximum depth of 18 metres. Some dives will be carried out as deep as 30 metres.

The number of training dives that can be carried out in a single day is limited to three with a final training dive being restricted to a maximum of 12 metres. The ascent at every dive has to be carried out no faster than 18 metres per minute (or slower depending on the instructors computer) and needs to incorporate a safety stop for 3 minutes at a depth of 5 metres.

The most aggressive profile under the water that PADI instructors carry out is for the entry-level course with open water diving. During this course emergency procedures are learnt and practice emergency ascents carried out. The instructor may have a number of students under the water simultaneously with whom he/she has to make these ascents. One of these ascents is where the air source is swapped with a buddy diver. There are also single (solo) ascents and controlled emergency swimming ascents. The instructor can chose to carry out the ascent skills on separate dives. They do not have to be carried out during the same diving session or with the same number of students.

With respect to a rescue diving course an instructor will be teaching and demonstrating skills such as a buoyant lift or the alternate air source ascent.

With respect to emergency procedures things that may happen to an instructor include a student bolting to the surface requiring the instructor to control their ascent. If the student makes

another uncontrolled ascent the instructor is responsible for ensuring that this is dealt with and managed so that they surface safely or that they remain in a controlled state under the water.

The rest of the diving environment is of low risk and there are no major physical activities taking place under water apart from the swimming. When and if an incident takes place an instructor would potentially be required to bring someone to the surface, lift them to the surface, or into the boat or onto the shore. Emergency ventilation may be required at the surface during a rescue. The most physical activities are only likely to occur during such emergency.

PADI instructors generally dive when training with a mixed enriched air/nitrox blend as opposed to diving on air due to the number of ascents carried out during the training.

### **3.1.3 Chris Sherman (HSE Chief Diving Inspector):**

I want to speak from a non-medical and largely personal perspective and in some trepidation being aware that this gathering includes the ‘greats’ of the diving medical world. The room probably contains different views, some of which are strongly held and possibly opposing, so I dip my toe into this water with care. My view is that this meeting is an event to be welcomed and I am here to learn and occasionally answer people’s questions (when appropriate).

It is worth recognising that as a whole the commercial diving industry is very conservative. If you consider the offshore industry, their kit and their procedures have not changed a great deal for a long period. This may be different from recreational diving that moves fast in its use and development of equipment and technical innovation. For the commercial diving world its conservatism is for a good reason. The legislation and the guidance that are in place now can almost all be traced back to serious, or fatal, accidents. This may represent the ‘bolting of the stable doors’ but these things are done for good reasons particularly in the context of the off shore industry. HSE is not opposed to change but my bottom line is that if we change any guidance (or rules and regulations) it must not leave people at greater risk to their health and safety (even greater perceived risk). I may have to face divers (or companies) who will say “you have changed the diving medical when it was already safe!”

I have been diving for a long time and am due my 29<sup>th</sup>, or 30<sup>th</sup>, annual diving medical soon and as I have never had to pay this may bias my viewpoint! My background is as a Naval diving officer, and as a saturation diver working for the ‘off shore’ industry before I joined HSE. I am still a reserve diver for the Navy and do a bit of recreational diving. I have not found the exercise component of the diving medical a particularly controversial issue with the people that I have discussed this with. A quick straw poll of other divers at HSE suggests that the exercising test in the medical is not particularly demanding (unless you have a particularly rigorous AMED doing the testing!). The general and I think widely held view, is that if you cannot pass the exercise test in your diving medical, you probably shouldn’t be diving. I stress this as a personal view and not the official HSE stance.

The issue for recreational diving comes down to whether the instructors should be regarded as at work or not at work. This whole question of volunteer instructors is a well-rehearsed issue that has not been resolved with PADI. Some people go to a lot of effort to avoid paying for the annual diving medical which is puzzling. I feel strongly about this and partly disagree with Erika that a lower standard of fitness/medical should apply to recreational divers. My experience is that diving ‘is diving’ for whatever purpose it is being carried out and it is dangerous to generalise about particular types of diving. Saturation diving can have its own mental and physical challenges such as living in a ‘sardine can’ for weeks on end but if when professionally carried out may not present too great a challenge. In contrast, a recreational

instructor with less support in place may face a very demanding dive. Therefore, we need to be careful to say that lower standards can be applied to other areas of diving.

The PADI standards are clear and very detailed for all circumstances but some PADI instructors may go outside the parameters of their training and these procedures. There certainly are people undergoing training regimes, or working with agencies, who are facing physical challenges under the banner of recreational diving. For example, people are regularly diving using mixed gases, with very heavy configurations of cylinders and rebreathers. Other examples include regular diving to 75 metres on oxygen-helium (or tri-mixes), multiple dives, provocative exposures and very long decompression periods. These activities may represent a minority of 'technical' divers' but the activities place significant physical demands on the diver.

The safety of the diver exposed to long periods swimming in water must be taken into account. If they do not function properly and are not physically fit to do the job when things go wrong, it is the student or members of the public whom are put at risk. 99% of the serious accidents in the recreational 'at work' field are to the student and not to the instructor. The questionable fitness and strength of one such instructor is known to have been the contributing factor to the rescue of a group of students going wrong.

The question is do we need to look at the fitness requirements for the worse case scenario, for example a student needing rescuing? Does that capacity need to be assessed at the diving medical or is it for risk assessment of each diving task? I do not object to the principle that the contractor, supervisor, and the diver have the legal responsibility to ensure that the task is competently carried out. However, if we remove exercise tolerance testing (or whatever else you call it) from the diving medical this could send an incorrect message about the requirement for physical fitness for diving.

I am happy that we maintain flexibility in our examination of the diving medical. Another issue that may need to be discussed at a future workshop is the impact of the Disability Discrimination Act. There are people with disabilities who want to become professional instructors but the question arises as to how best to assess their level of fitness to rescue e.g., a student in distress. In principle this is something that can be dealt with by procedures and proper risk assessment but may require another person in the water to provide the rescue function. There has got to be a minimum level of required physical fitness to deal with the worse case scenario. In recreational diving this means pulling your unconscious or panicking student out of the water, or rescuing your buddy in a commercial or military dive.

## **3.2 Feedback From Discussion On Regulatory Issues (David Snashall -Chair)**

### **3.2.1 Numbers of diving medicals:**

There are 5,000 HSE medicals a year and the numbers are remarkably constant with a small decline in non-recreational commercial divers but an increase in recreational commercial divers. HSE does not recognise most overseas AMED medicals (currently only recognises Norway) and spends a lot of time with the relevant recreational agencies encouraging and enforcing amongst the commercial sector the need for the HSE medical. HSE estimates that 3,000-4,000 recreational instructors are 'at work.' This exposes ~40,000 members of the public every year to potential risk in this area. The Armed Forces are estimated to employ around 1,500 divers (of all types).

### **3.2.2 Fitness requirements:**

Common to all sectors there is the need to have physical ability to deal with the effort involved in unforeseen rescue situations. The physical demands and fitness requirements to deal with an emergency such as a rescue cannot easily be quantified.

### **3.3 Safety of the Fitness Test**

#### **3.3.1 Dr Stephen Glen (Consultant Cardiologist) [SEE HANDOUT 1]:**

The point has been made that commercial divers will be fit individuals and unlikely to have coronary heart disease but this assumption is flawed. Whatever population of workers you look at there are people with underlying cardiovascular problems and these are found with remarkably similar prevalence amongst different groups. There are around 10-12% of individuals with positive exercise test signs of myocardial ischaemia and or chest pain so this issue should be of concern to us. I do not have the age, or sex distribution, of cardiovascular illness amongst commercial divers but we are probably talking predominantly about males within the traditional commercial area and of age range from early 20's to the late 40's. Data from other groups of workers such as fire fighters, Norwegian sea pilots, sea captains and police officers, demonstrate a fairly high prevalence of coronary artery disease.

The concern is that if you do exercise tests in any form then you have to do them safely. To carry out a test and not actually monitor the cardiovascular function e.g. ECG and blood pressure, is to take a great risk. If you do get a positive result for these measures is this predictive? This is a huge thorny issue and has been looked at amongst various groups of workers in the US. A meta-analysis of ~23,000 people examined individuals with a positive exercise test and followed them for a couple of years to identify subsequent cardiovascular events. This showed a risk of further disease that was ~4 times greater than for those with a negative test result. However, even for those individuals with a negative exercise test result, a significant number subsequently suffered an infarct or cardiovascular event.

The exercise test may be used to assess fitness but the current test is not a good screen for coronary and arterial disease. It is asking medical examiners, who may not have the appropriate facilities (in the opinion of various expert bodies) to look after potentially life threatening cardiovascular events. The main recommendations from groups such as the American College of Cardiology, the American Heart Association (on the whole we follow the American guidelines), the European Society of Cardiology, and the British Cardiac Society, all suggest that if you are going to do an exercise test you need to view an ECG (12 leads) throughout the testing. You also need to monitor blood pressure throughout the test and should have appropriate resuscitation equipment and a level of care with staff appropriately trained in resuscitation procedures. Clearly this is not generally the case.

Is it worthwhile exercising asymptomatic individuals? The answer is probably no since this is not a worthwhile test for coronary artery disease. If you pick high risk individuals with positive family history, those with high cholesterol, background of diabetes, and in particular males over the age of 45 you will identify patients with asymptomatic coronary artery disease. It is worth bearing in mind that young people often have single vessel disease and an exercise test will only pick up about 80% of these individuals with this underlying defect. Therefore it is a very insensitive test.

My perspective is that we are placing AMED's in a medically indefensible position when we ask them to carry out exercise tests using inadequate facilities and without proper supervision.

### 3.3.2 Dr R. Vecht (Consultant Cardiologist):

In 1948 two papers were published which examined the incidence of coronary atheroma amongst young American soldiers killed in World War II and these reported quite a high incidence of disease. Two further studies (one Korean one Vietnamese) also reported quite a high incidence of coronary arterial disease (amongst 20 years old regular soldiers). These results underline the importance of obtaining history of the familial background, before exercise testing is carried out.

One of the questions that we have addressed is whether it is ethical to perform a stress test when there is the risk of provoking a cardiovascular event? In 1977, Ellestad published a study of 1,500 exercise testing centres in the US. Altogether this included the results of 450,000 treadmill tests, 45,000 bicycle ergometry tests, and 25,000 Masters step tests. The reported incidence of infarction related to the testing was 3.5 per 500,000 tests. In addition to this there were 48 cases of serious arrhythmia and a mortality incidence of 0.5 per 100,000 individuals.

Kaltenbach published a study of exercise testing in Germany and examined the results of a 1,000,000 stress tests (mostly bicycle tests). Amongst 700,000 patients they reported 17 deaths, 96 severe complications, with a mortality of 2 per 100,000. However amongst a group of 350,000 sports people there was no reported mortality, and no morbidity.

My personal experience during 30 years of carrying out my (~ 500-600) stress tests per year, is of recording 3-4 infarct events (of which all the patients survived) and two deaths. One of these incidents included a 40-year old man with a negative stress test who subsequently collapsed in a pub. The other was of a GP who had an infarct occluding his right coronary artery. He was a very fit man (non-smoker) but a year later he came back with an infarct in the left anterior descending (LAD) vessel and he couldn't make up his mind whether he wanted to have an operation. We carried out a stress test and the results were satisfactory. He then completed a thallium myocardial infusion test but dropped dead cycling horizontally and we could not resuscitate him.

The other thing I wanted to discuss was the physical activity readiness questionnaire (PAR-Q) included amongst the paperwork circulated prior to the meeting. I am not happy with the content of the questionnaire and find some of the questions inadequate particularly if it is to be used to decide who needs a stress test. First of all the questions about the symptoms are not adequate, a lot more information about the nature of the chest pain, and whether they get breathless, is required. There is no mention of palpitations, body weight, etc, and there are no questions about family history. It is very relevant to know that a patient's father died at 42 of an infarct, whether the person is hypertensive, or whether they have a raised cholesterol level (**for response see Appendix II**). Having worked as a registrar for the insurance industry I have seen a number of people who have taken out life insurances and not divulged all their relevant medical history. When they dropped dead and the insurance company found out the relevant facts (such as persistent chest pain) their widows did not get a penny of insurance. If you are going to use such a questionnaire it should be mentioned that it is against the law and punishable to provide wrong information.

Finally during the course of the investigation, one thing that I always mention is the validity of echocardiography. This is an expensive test but it can pick up young people with cardiovascular abnormalities. Young people can drop dead from hypertrophic cardiomyopathy and this can be detected quickly on the echo. Being an athlete does not prevent you from having heart disease.

Finally the last thing I want to say is about the use of recreational drugs. When I have asked others about this, I am amazed at the number of ordinary decent people who admit they are taking drugs such as cocaine. This drug is very bad for the coronary arteries and the PAR-Q questionnaire should contain questions that ask about previous use of recreational drugs.

### **3.4 Feedback From Discussion On Safety Issues (David Snashall - Chair)**

#### **3.4.1 Significance of the first or initial medical at the start of the diver's career**

The use of a screening questionnaire and confirmation of the medical history by e.g., their GP, was seen as very important step to ensure that divers can provide an adequate medical history when they come forward for the diving medical examination. There were issues surrounding the cost and time if GPs were expected to provide this information, obtaining GP records was currently a complex problem and the quality of these records can vary significantly. There is a lack of a standardised approach for recording the relevant aspects of a medical history and unless this problem is solved it will always present an obstacle to the AMED in their assessment of 'fitness' to perform the exercise test.

#### **3.4.2 Patent Foramen Ovale (PFO) screening**

1 in 4 of the population have this condition. Screening is done reactively following an unexpected case of neurological decompression illness (NDCI) as the presence of PFO does not mean that diving can be excluded as an activity. There is a selection effect as most commercial divers have a background first as sports divers so symptomatic PFOs may already come to light but the onset of symptoms is rare and unpredictable.

#### **3.4.3 The step exercise protocol:**

AMEDs differ in their chosen protocol for step \ exercise testing. Usually the test lasts 5 mins, and some AMED's use a general health questionnaire as a screening tool preceding the exercise testing. Some AMEDs use an ECG at the end of the step testing whilst others monitor pulse rate throughout. Other practitioners may administer the step test but on the basis that an AMED reviews the results and decides on fitness for the test. Overall, there is a lack of standardisation of the protocol, for example what height to set the step box. Some AMEDs do use visual and ECG monitoring and may have resuscitation skills and equipment such as a defibrillator. There are differences in standards of the exercise testing when used to determine aerobic capacity and cardiovascular fitness (stress testing) in the hospital setting by trained Cardiologists. There is a balance to be struck between the assessment of function versus diagnosis.

#### **3.4.4 Role of step \ exercise testing**

Is the purpose of the test to measure aerobic capacity and cardiopulmonary response to exercise, or to detect IHD? The test cannot be used to detect silent coronary artery disease, as it is not a validated for this endpoint. It is unlikely to be a useful screening test for diving induced pulmonary oedema because of its low sensitivity and the need for continuous blood pressure monitoring. Some subjects develop hypertension and demonstrate sudden blood pressure rise during the exercise. Research suggests this occurs with a prevalence of ~1% amongst sports divers. The level of exercise can be regarded as health promotion tool to encourage appropriate standards of physical fitness however it needs to be remembered (because of increased gas density and viscosity), that exercise at raised environmental pressure is limited by pulmonary performance rather than by cardiac fitness.

### **3.4.5 Role of exercise stress testing using the Bruce protocol**

The guidance from the American College of Cardiology regarding screening symptomatic individuals suggests that an age over 45 years (for males) is critical and other risk factors such as family history, raised cholesterol, and diabetes should be taken into account. There are fewer false negatives when screening individuals who have been identified as having one or other of these risk factors. The significance of the stress test will vary with age and the number of associated risk factors. However, stress testing will miss a significant proportion of individuals with single vessel disease, particularly younger people. The published data suggests single vessel disease will be detected only in ~80% of younger people indicating an unacceptable insensitivity. Stress tests are much more likely to be positive in the case of triple vessel disease. Angiography has limited prognostic value and there is always the risk of arrhythmia and cardiac arrest in symptomatic patients. There is uncertainty around the prognostic significance of a positive stress test but studies have suggested that the risk of a subsequent cardiovascular event is likely to be ~ 4 times higher. However, a significant number of people with a negative stress test go on to have some sort of cardiovascular event.

### **3.4.6 Age of diver:**

The 'cut off' could be set at 45 for males and 55 for females as these are regarded as the 'watershed' for increased risk of a cardiovascular event due to an increased rate of ischaemic heart disease (IHD). However there is no evidence that cardiac arrest amongst working divers over such age limits is a significant risk requiring early retirement. The published evidence suggests a prevalence rate of around 10% in many worker populations.

### **3.4.7 The Driver Vehicle Licensing Agency (DVLA) screening questionnaire:**

The DVLA employ a validated screening questionnaire for LGV drivers, which is regarded as an effective tool to identify those with the appropriate risk factors. The possibility of developing a valid cardiac screening questionnaire based upon the DVLA model could be examined by a working party.

### **3.4.8 Use of resuscitation equipment and training:**

The availability of appropriate resuscitation equipment and adequately trained individuals during the exercise testing was essential as these procedures should only be carried out following a risk assessment. It is reasonably foreseeable that a GP will encounter patients with acute MI so they need to manage and assess the risks. The question is whether those who carry out exercise testing will have this equipment and trained staff in place? There is always a risk of myocardial infarction or collapse occurring at the GP' premises but it is better that if this event occurs it is within an environment where it be managed rather than it occurring underwater.

### **3.4.9 Limits for the testing regime:**

As a test for ischaemia, it is normal to apply a limit of 220 minus age as a target heart rate according to the predictive tables. For a typical male diver age 40 you would expect them to go for at least 12 METS in the Bruce Protocol and this would correspond to 12 - 15 minutes of exercising.

#### **3.4.10 Step testing and risk factors**

Should additional testing for the over 45 year old male with no risk factors (e.g., diabetes, family history of IHD\sudden cardiac death, high cholesterol, smoking, hypertension and homocysteine) be carried out? Fasting blood glucose, random cholesterol and blood homocysteine levels have all been proposed as tools to screen male divers over the age 45. These additional tests could be introduced e.g., once the medical examination of 44 year old males has occurred. This screening could also be delivered by pharmacists as many already provide glucose and cholesterol tests. However, the AMED would need to have results from a fasting glucose assay. Before proceeding, and there are other issues of cost and complexity around the introduction of such medical tests.

#### **3.4.11 How frequently should stress tests be carried out above the age of 45?**

The answer to this is difficult to determine and there is no validated evidence base to guide the decision. Some studies have limited the outcome to this question to a 3-5 year period. Should cardiovascular screening be carried out only for those males over the age of 45 who have other positive risk factors, or for cases where there are additional public safety issues (e.g., instructors working with students)? Screening at age 45 for coronary arterial disease would have to be carried out by a cardiologist. However this would escalate the costs for the AMED medical as private consultancy tests carried out by a cardiologist are ~£300 per evaluation (based upon current DVLA rates). There are other issues such as delayed waiting time because these skills are in short supply, and also perceived age discrimination for those over the age of 45. Many divers are self-employed and could not cover the additional costs if this had to be done frequently the age point. It could be seen as sending a confusing message to encourage divers to exercise regularly to keep fit but then to decline to subject them to the exercise test because they were positive for one of these additional factors.

#### **3.4.12 Applying population based risk factors.**

Is it wise to base a 'cut off' age for further testing on the basis of average population-based estimates for a threshold cardiovascular risk? Should the decision be based upon a stratification of the risk across the population (males or females) including a weighting for other risk factors?

#### **3.4.13 The economic argument.**

The UK oil industry has set a cost threshold for saving a single life and if the cost for prevention was significantly above this threshold, it was concluded that something was wrong with the overall approach and that the relevant procedures needed to be re-examined. What is required in this role is a proper 'cost benefit' analysis to determine the potential number of lives saved as a consequence of introducing additional tests compared to the current mortality rate. Assuming that one third of the five thousand commercial divers are over the age of 45, the additional costs for the standard medical plus stress test would be ~£500,000 compared to the medical examination alone. These costs would have to be borne by individuals and small businesses and this does not include the additional cost to government for introducing and monitoring such a change.

#### **3.4.14 Calculations to determine ‘acceptable’ accident rates:**

The Civil Aviation Authority determines the ‘acceptable’ medical incapacitation rate based upon an accident rate that is technically and socially ‘acceptable.’ This rate cannot be set at zero but has to be set very low. HSE could consider the need to introduce such changes based upon the calculation of acceptable risk.

#### **3.4.15 The need for improved data**

There are one, or two, incidents of divers having a myocardial infarction during step testing and some cases of arrhythmia. Based upon 30 years of testing and ~5000 medicals the question is what is the scale of the problem? There is inadequate data on the risk of myocardial infarction for divers during step testing and this deficiency needs to be addressed. In contrast, it is estimated that 5-10 divers die each year from IHD but it is not clear how many of these are sports divers, and how many are commercial divers? However, it could be argued that it is better for an occurrence of myocardial infarction to occur in the GPs surgery (or AMEDs premises) rather than in the water.

#### **3.4.16 What the MA1 states about testing**

The MA1 currently allows the AMED to use their discretion to refer divers for further investigation if this is clinically indicated. It is argued that these decisions should always be based upon sound medical findings, common sense, and a rational risk assessment of the individual circumstances. The decision is to be made by the AMED but there may be a need for further clinical information. The suggestion is that those with an elevated risk (based upon medical history and specific risk factors) should be more closely examined.

#### **3.4.17 Responsibility of the employer**

It is essential that the employer undertake a risk assessment of the work task. However it is the responsibility of the diver to be (and to remain) physically fit for diving. The medico-legal risks that could provoke litigation are clear. There is a hierarchy of evidence to guide this decision making process.

### **3.5 Issues of Test Validity**

#### **3.5.1 Dr Gavin Anthony (Exercise Physiologist, QinetiQ):**

I will summarise the physiological evidence about the work rates that divers are likely to experience when they are in the water [SEE HANDOUT 2]

I have broken this summary into three sections:

***Controlled underwater cycle ergometry:*** This type of test is based upon use of an underwater cycle with careful control and close monitoring. Breathing test apparatus is normally used but it is also important to look at what the divers can do. This testing takes the subject through a range of helium based gas mixtures (from 0 – 360 m) with air, or Nitrox mixtures (50 m) and can be applied to a range of breathing apparatus. There is a simple open circuit to rebreather systems as

well as conventional open circuit supplies. Using this system a wide range of work rates can be examined.

The data we have generated involves divers who are fit to the current HSE criteria but I should emphasise that this work is primarily carried out in a military environment but does include divers military and standard commercial divers, as well as our own divers.

Under these test conditions divers can achieve ventilation rates of 100 l/min or greater within a two mins test period. Depending on body mass, a  $\dot{V}O_2$  of  $\sim 3$  l/min or greater is achieved throughout the full range of diving activities.

*With regard to endurance exercise* there are people using cycle ergometry (under the laboratory testing regime) who can achieve a  $\dot{V}O_2$  of  $\sim 1.6$  l/min for up to 4 hrs with a 40 l/min ventilation rate. However taking depth and endurance into consideration you are not going to achieve this  $\dot{V}O_2$  in a real 50 m dive on air over a 4 hr period. These values are derived from a controlled laboratory test environment.

*We have also examined work rate* amongst individuals trying more realistic tasks and this is applicable to fit young males and to the recreational diving tasks. These tests suggest that subjects can swim for two hours as long as they can self-select their rate of progress. However by forcing them into a fixed rate of say a knot, then a  $\dot{V}O_2$  of greater than (or equal) to 2 l/min is regularly achieved for a 2 hours period. Whereas if you drop the fixed work rate down to  $\frac{3}{4}$  knot then  $\dot{V}O_2$  drops greater than (or equal) to 1.0 l/min but this can be sustained reasonably for 3 hrs. Where, unfortunately we have limited data is for underwater 'engineering type' tasks. For 'warfare type' tasks we have recorded routinely a  $\dot{V}O_2$  of about 1.4 (or greater) for periods longer than 1 hr.

The most significant procedures we identified during this mornings discussion were the emergency diving situations. When we are required to investigate unfortunate situations such as incidents (or fatalities) it has been found (based upon limited data) that people have recorded ventilation rates of up to 70/80 l/min. This was associated with  $\dot{V}O_2$  ratio in the order of 3 or greater. Relating this to current standards of 4 litres/min  $\dot{V}O_2$  then for an 80 Kg man this equates to 50 ml/kg, and this is just over 14 METS, just over the limit stated in the current HSE guidance for exercise testing.

People can clearly achieve 3 – 4 l/min between 3 and 4 mins but if you are look at endurance and stamina then a  $\dot{V}O_2$  of  $\sim 2$  l/min (or more) can be sustained for a couple of hours or more in water with divers using breathing apparatus and with work rates consistent with real diving activity. In the emergency situation rates of 70-80 l/min may apply but this will depend on body mass and equates to  $\sim 14.5$  METS.

### **3.5.2 Dr Keith George (Exercise Physiologist, Liverpool John Moores University) [SEE HANDOUT 3]:**

We test many different types of athletes and constantly battle with two conceptual problems:

- Should we be testing them in the first place?
- If you are going to apply a test, is it going to provide meaningful information (i.e. is the test valid)?

When it comes to the concept of test validation there are many things that should be considered. An area of great concern to the exercise scientist is whether things can be measured relevant to

the desired or specific endpoint of the test. The question to pose is ‘Is it a test of general fitness, job-specific fitness and/or a test of cardio vascular disease status?’

**Task Specificity:** Task specificity is an important component of many exercise tests performed in the sporting and exercise world. This factor may influence exercise tests for divers if a job-specific test is required within the medical. For example take elite cyclists that find it very difficult to run on a horizontal treadmill as their muscle are attuned to the cycling stance.

Exercise physiologists are also interested in whether you are looking at whole body or small muscle mass activity. The aerobic capacity test is based on the amount of metabolically active tissue. When you compare treadmill to the bike or even to step testing there are going to be substantial differences in the amount of muscle mass involved. The issue may be what muscle activity (or whole body) is needed for commercial diving work?

These points illustrate the problem, what is the appropriate test to take into account the type of activity encountered by an individual doing a particular job. There are obvious problems when looking at commercial diving as there are no pre-validated test scenarios or protocols. Coming up with a job-specific test of fitness within the yearly medical would be complex, time consuming and potentially impractical. For evaluating fitness to dive the key point is whether you can really get any activity specific or environment specific, information that is meaningful?

**Choosing a testing protocol:** If the test is not job or task-specific (or as we have heard not valid in determining coronary artery disease status) then to get general fitness information you have to consider the testing protocol. To get meaningful data you then need to consider graded tests at a particular intensity of exercise. The classic stress test is graded in intensity, for example using a treadmill. Single intensity work tests may address other issues like steady state performance and muscle efficiency that can be generated without changing the rate of work. The issue of concern is what exercise intensity you would choose and would this be universally applied?

**Reliability:** An important component of the test validity is reliability. If a test is not reliable it is not valid. This requires test precision so that it can be used as a sensitive measure of changing fitness status or changing health status. Natural biological variations are substantial within season, and even within weeks, and therefore it is difficult to generate precise physiological test results. The issues that need to be considered for the yearly medical include which criteria are to be applied to interpret the test results.

**Measurement:** The next important concept is what is measured when a test is performed? A lot of the published data refers to the use of  $\text{VO}_2$ , METS, and respiratory exchange ratios but there is some value in looking at performance data. There are other health, (and physiological) parameters that should be considered when looking at steady state exercise, for example blood lactate concentration.

### **3.6 Feedback From Discussion On Issues Of Test Validity (David Snashall -Chair )**

#### **3.6.1 Muscle mass**

Muscle mass and strength determines the ability to move or drag objects not the max  $\text{VO}_2$ . For example, the recovery of an injured diver into a bell by a diver using mixed gases is known to have taken longer than would be expected for a recreational instructor. The rescue of a diver

'up-current' on the surface to a boat moored at a buoy requires considerable endurance and power.

### **3.6.2 Rescue scenario**

For a rescue scenario under two minutes duration, aerobic endurance and power are likely to be imprecise predictors of outcome.

### **3.6.3 Risk assessment:**

The diver's employer should undertake an assessment of fitness as part of any risk assessment of diving activity. The risk assessment would be more relevant if it included the task, use of equipment, distance and depth to be travelled and effort involved. Does evidence of normal working function and performance demonstrate a divers fitness for work? An aware employer will base their decision upon selection, training, diver rotation, communication, modified techniques and use of equipment to reduce work demand and fatigue. High levels of supervision in some commercial areas ensure that the risk of fatigue\exhaustion is reduced. All working divers have been through diver rescue training beforehand and have demonstrated 'in water' ability. It is the role of the diving supervisor to ensure that divers keep within these limits. The diver is also personally responsible to remain fit throughout the year.

### **3.6.4 Selecting a test:**

There is no ideal single exercise test to measure aerobic and physical demands and therefore the capacity required for all possible mixtures of work e.g. dive activity, equipment configuration, gas mixtures and emergencies. No single test can measure this array of activities. All the current protocols have limitations and exercise testing is only a surrogate for job specific fitness that addresses cardiorespiratory capacity. Step testing is an indirect method of calculating  $VO_2$  and it cannot measure endurance capability for commercial diving activity. Failing the test leads to further investigation as required.

### **3.6.5 Issues for removing the exercise test.**

Currently the test provides some feedback to the diver on his\her fitness and a baseline for future comparisons. It should also be regarded as a health promotion tool and a reminder to the diver to keep fit. It could therefore be regarded as a motivating factor.

### **3.6.6 Step tests:**

These are to be preferred over the bicycle ergometer for their simplicity, cost, convenience, and because they are adequate for purpose. A timed swimming test was suggested but was considered impractical by some. A standardised step test protocol was recommended as long as the test is done by the AMED. There are alternative tests that could be completed by the diver prior to seeing the AMED but this would raise an important question concerning verification of the test results.

## **4.0 CONCLUSIONS AND SUMMARY OF THE WORKSHOP**

### **Dr Snashall (Chair)**

I am going merge two of the sections because they link naturally together and I would like to suggest that we try to reach consensus if this is possible. Perhaps we may be able to achieve a position statement at the end of the discussion.

### **4.1 Medical examinations by AMEDS**

We are trying to be practical and to fulfil certain requirements of validity and of safety and the following questions therefore arise:

- What should happen at the yearly medical examination?
- What should be the variation in the initial medical examination?
- Safety of exercise testing, how it can be ensured?
- The role of the employer – at what point is it reasonable to expect the employer to take over some of the testing as part of a risk assessment, and so reasonably fulfil their duty of care?

#### **4.1.1 Medical examinations**

During medical examinations the practical aerobic fitness test (I'll call it that) is still a reasonable thing to do. It fulfils a basic requirement of measuring cardio-respiratory fitness. It also acts as a warning to people who are becoming less fit. It is a form of health promotion and it can motivate people. However in terms of predicting or detecting cardiovascular abnormalities it is a crude and inappropriate test. With respect to the type of test it is considered unnecessary to use a treadmill and or bicycle ergometer and step testing is as good as anything and certainly more practical. This reduces the arguments to the basics but hopefully provides an acceptable summary.

#### **4.1.2 Practical tests**

A practical test of aerobic fitness should continue to be used and the step test fulfils this requirement. The reasoning behind the use of this method is that it is a crude measure of aerobic fitness; it acts as a early warning; and is also a health promotion message (although the evidence base for this is not solid).

#### **4.1.3 Expected fitness**

To this we would have to add (as is in the guidance at the moment) a level of expected fitness expressed in units. I gained the impression from the physiologists that if people were to attain the work capacity already specified it would be a reasonable 'cut off' point. Without more evidence I don't think we can say much more than that. The level at which it is pitched at the moment is 13 METS and 40-45 mls/kg/min. I think it should be pointed out that there are difference between the cardiac stress test (according to cardiological protocols) and the expected work capacity to be attained during the diving exercise test.

#### **4.1.4 Initial medical**

We have accepted that the initial medical examination, should be of a different and slightly deeper character. One of the deficiencies some people thought concerned the reliability of using a self-completed screening questionnaire. There was a need (in order to make a reasonable risk assessment) for past medical history to be objectively recorded. There are two ways of doing that: one is to write to general practitioners asking for a relevant medical information which I think is impractical for a number of reasons. The DVLA testing regime suggests a new practical scheme in the form of a questionnaire sent to the GP saying “has this person had heart disease? Do they get migraine? Do they have epilepsy etc?” This would be easy to fill in and the diver should do this before under going assessment by the AMED.

#### **4.1.5 Screening Questionnaire**

There was the suggestion that a questionnaire could be given to the diver to be filled out when they attend their first medical. This would allow the AMED with further questioning to achieve the required clarification. More work is needed to put together a decent questionnaire that can be tested and validated to cover all relevant aspects, including psychological problems, asthma, diabetes etc. It does not need to specifically address cardiac disease although it would include questions about this. Having completed this the AMED would be in a better position to decide whether testing should take place or whether further clinical examination is warranted.

#### **4.1.6 Age Factors**

On the issue of the safety of exercise tests we have agreed as a precautionary principle that the exercise tests should be a type of step test carried out at the same rate (or work capacity) as is done currently. We have been told that time has moved on and the way it is done at the moment might have safety implications with cardiac problems occurring during the testing. The risk for males is higher over the age of 45 years based upon the evidence provided by studies in United State. For those males under 45 years of age a medical examination and exercise test can be carried out as described. For the over 45 years age group there is a greater risk of cardiac failure during the exercise test.

#### **4.1.7 The Employers responsibility:**

The employer has a responsibility to conduct a risk assessment before each dive, assessing fitness to dive and capacity to cope with emergencies. A timed swimming test may help the supervisor to assess the diver’s pre-dive fitness for the allotted task.

## 5.0 APPENDICES

### 5.1 Appendix I

#### 5.1.1 Handout 1

##### 1. Are professional divers likely to have coronary artery disease?

No professional diver studies available. Others include:

*Fire fighters: Near-maximal ECG stress testing and coronary artery disease risk factor analysis in Los Angeles City fire fighters. Barnard RJ et al. J Occ Med 1975;17(11):693-5. 10% had ischaemic exercise test results. Two with negative tests died following MI subsequently.*

*Norwegian sea-pilots: Coronary heart disease in Norwegian sea-pilots. Erikssen et al. Acta Med Scan Suppl 1981;645:79-83. 12% had ischaemic exercise test results.*

*Sea captains: Latent ischaemic heart disease in sea captains. Mundal et al. Scand J Work Environ Health 1982;8:178-84. 10% had ischaemic exercise test results.*

*Police officers: Frequency of physical activity, exercise capacity and atherosclerotic heart disease risk factors in male police officers. Williams et al. J Occup Med 1987;29(7):596-600. 9% had ischaemic exercise test results.*

All groups studied had high levels of cardiac risk factors.

##### 2. Are the results predictive?

Relative risk for events in a meta-analysis of 9 studies of asymptomatic patients (22,585) varies according to criteria; in general relative risk is around 4x normal. False positive results are common; excess risk of angiography.

##### 2. Is exercise testing safe?

Risk of death or myocardial infarction estimated at 1 per 2500 tests.

##### 3. What facilities are required?

“The ECG, heart rate, and blood pressure should be monitored carefully and recorded during each stage of exercise... The patient should be monitored continuously for transient rhythm disturbances, ST segment changes, and other electrocardiographic manifestations of myocardial ischaemia.”

ACC / AHA 2002 Guideline update for exercise testing.

##### 4. Is it worth exercise testing asymptomatic individuals?

“Asymptomatic male patients older than 45 years with one or more risk factors (hypercholesterolaemia, hypertension, smoking, diabetes or family history of premature CAD) may obtain useful prognostic information from exercise testing”.

ACC / AHA 2002 Guideline update for exercise testing.

# Diver work rates

## HSE Meeting - Exercise testing for divers

- **Controlled underwater cycle ergometry**
  - Gas mixtures: Helium based 0 to 360 m  
Air/Nitrox 0 to 30 m (50 m)
  - Breathing apparatus: SCUBA - Open circuit  
- Rebreather  
Surface supplied - Open circuit
  - Divers fit to current HSE criteria
  - Acute: Achieve  $V_E \geq 100 \text{ l} \cdot \text{min}^{-1}$  BTPS  $> 2$  min  
( $\text{VO}_2 \sim 3.0 \text{ l} \cdot \text{min}^{-1}$  STPD)
  - Endurance: Achieve  $\text{VO}_2 \geq 1.6 \text{ l} \cdot \text{min}^{-1}$  STPD up to 4 hr  
( $V_E \sim 40 \text{ l} \cdot \text{min}^{-1}$  BTPS)
- **Diver work rate studies (SCUBA)**
  - Fit young males
  - Swimming: - Self selected rate
    - Fixed rate (1.0 kt)  $\text{VO}_2 \geq 2.0 \text{ l} \cdot \text{min}^{-1}$  2 hr
    - Fixed rate (0.75 kt)  $\text{VO}_2 \geq 1.0 \text{ l} \cdot \text{min}^{-1}$  3 hr
  - General tasks:  $\text{VO}_2 \geq 1.4 \text{ l} \cdot \text{min}^{-1}$  for  $> 1$  hr
- **Emergency scenarios**
  - Analysis of incidents and fatalities
  - Recorded  $V_E$  70 to  $80 \text{ l} \cdot \text{min}^{-1}$  BTPS  
( $\text{VO}_2 \sim 3.0 \text{ l} \cdot \text{min}^{-1}$  STPD)

**HSE Workshop: Exercise Testing For Divers**

**VALIDITY:**

*“Does the test measure what it purports to measure”*

**Are we assessing fitness for specific work task,  
general fitness or health status?**

**Specificity – Whole body vs. smaller muscle mass  
Activity specific  
Environment specific**

**Protocol - Graded vs. steady state  
Continuous vs. discontinuous  
Direct vs. indirect**

**Measurements - Performance vs. physiology  
Performance vs. health**

**No validity without reliability**

**RELIABILITY:**

*“The consistency of test scores or measurements given  
the same tester, testee and test environment”*

**Greater Precision – Greater Sensitivity to Change**

**Human biological variation**

**Assessment of reliability**

Keith George, PhD

## 5.2 Appendix II

SF615



**DEVON & CORNWALL  
CONSTABULARY**

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Dear Dr Rahman

Further to my letter to you dated 8 June 2004 I am writing to tell you that I had a meeting here in-Force with our Force Physiotherapist and our Force Physical Education Officer. With reference to the draft abstract of presentations and discussions we make the following further observations:

- We would not regard our MA1 exercise test as a cardiac stress test
- The Par Q questionnaire which was criticised by Dr Vecht does not pre-empt a cardiac stress test but a submaximal demonstration of physical activity and ability
- We agree, however, that our Par Q questionnaire could be improved and we are going to be adding questions concerning exercise provoked irregular pulse/palpitations
- We already have access to a defibrillator and we are now considering whether we should have access to oxygen and face masks
- Medical staff undertaking this exercise testing are and will remain Cardiac Life Support trained

The purpose of our Par Q questionnaire is to reduce the likelihood of unnecessary medical screening in a basically very healthy population. You may be interested to know that when we undertake exercise testing that moves into an anaerobic phase we use a 12 lead cardiac monitor and employ Borg Scale Rating of Perceived Exertion.

I hope that this further information is of interest.

Yours sincerely

Dr John CHALLENGOR FRCP FFOM  
Senior Consultant Occupational Health Physician  
Head of Occupational Health



INVESTOR IN PEOPLE



Awarded for excellence