In: Pollock NW, Godfrey JM, eds. Diving for Science 2007.
Proceedings of the American Academy of Underwater Sciences 26th Symposium.Dauphin Island, AL: AAUS; 2007.

Physical Fitness of Scientific Divers: Standards and Shortcomings

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Abstract

Scientific diving standards provide guidelines for program oversight, crew and equipment requirements, and diver selection. Diver selection is primarily based on medical fitness and physical competency criteria. Physical competency is generally evaluated through certification records and initial tests of swimming skills and in-water diving abilities. Continuation of active status requires periodic medical evaluation, current emergency care certifications, and documentation of diving activity exceeding minimum requirements. While individual institutions and programs may require additional evaluations, formal requirements for periodic assessment of physical fitness are notably absent from most parent standards. This may have evolved from an expectation that medical evaluation would adequately address physical fitness or that inadequate physical fitness was not an issue in the scientific diving community. Problematically, medical evaluation may not provide an effective evaluation of physical fitness, and physical fitness within the scientific diving community cannot be assured given societal trends toward decreasing fitness. This paper reviews the physical fitness-related content found in a cross-section of institutional, national and extra-national scientific diving standards and offers suggestions for formalizing periodic evaluation of physical fitness.

Introduction

The evolution of labor-saving and communication technologies has increased the prevalence of sedentary lifestyles in developed countries. Increased access to a wide range of convenient and calorically dense foods has challenged efforts at personal restraint. Despite the known benefits of physical activity, more than 50% of American adults are not active enough to provide health benefits, and 24% are classified as completely inactive (CDC, 2007).

Assessing physical fitness on a large scale is impractical, but surrogate measures that provide estimates on a population scale are useful. Body mass index (BMI) is one such estimator. BMI is not a measure of body composition but a simple integration of height and weight (BMI = weight in kg / [height in m]^2) used to assign individuals to categories presumed to reasonably describe fatness. Categories include 'normal' (18.5-24.9 $kg \cdot m^{-2}$), 'overweight' (25.0-29.9 $kg \cdot m^{-2}$) and several subcategories of 'obesity' ($\geq$30.0 $kg \cdot m^{-2}$). While BMI categorizations penalize individuals with well-developed muscle mass, the technique is useful for large-scale studies when more sophisticated measures are unavailable.

According to BMI estimates, the number of American adults considered obese has more than doubled from 1960 to 2004 (Figure 1) (CDC, 2006). Even allowing for some miscategorization, this is a disturbing trend.

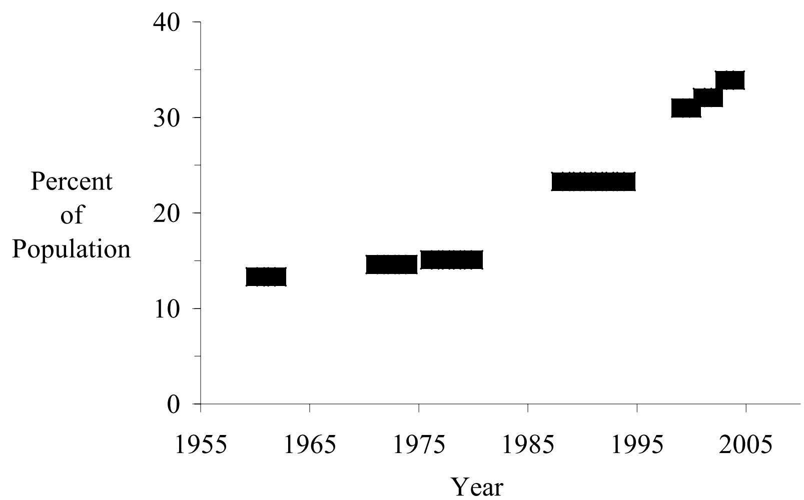

Figure 1. Trends in BMI of adults categorized as obese (30.0 kg·m^{-2} or greater) among American adults 20-72 years of age from 1960 to 2004 (CDC, 2006).

The preponderance of high BMI values is also evident in mortality data from the North American recreational diving population (Vann *et al.*, 2004; 2005; 2006). Data from 2002-2004 (n=199) identify 48% of deceased divers as obese and an additional 32% as overweight (Figure 2).

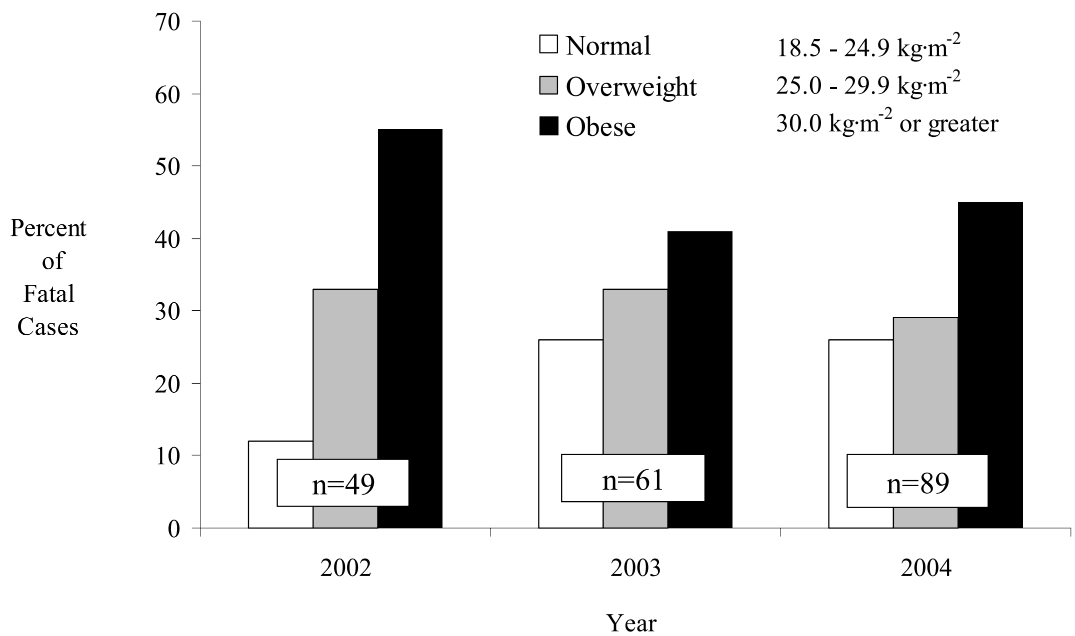

Figure 2. Classification of DAN recreational diver fatalities by BMI for 2002, 2003 and 2004 (Vann *et al.*, 2004; 2005; 2006)

Similar trends, if present within the scientific diving population, might threaten divers' physical capabilities to safely perform under normal and emergent conditions. Since scientific divers experience similar societal pressures, concern is warranted. Problematically, minimal information is available regarding physical fitness of scientific divers. This paper will consider existing standards and discuss possible alterations in practice and regulation concerning diver physical fitness.

Methods

Physical fitness is frequently defined in terms of cardiovascular and muscular endurance, muscular strength and flexibility. A range of proficiency tests can address these elements of physical fitness.

A review of major institutional, national and extra-national diving standards was conducted to identify the physical fitness-related components. Documentation was found for: American Academy of Underwater Sciences (AAUS) (2006); Australia/New Zealand Occupation Diving: Scientific Diving (AS/NZ) (2002); Canadian Association for Underwater Sciences (CAUS) (1998); Canadian Coast Guard (CCG) (S. Simms, pers. com.); US Coast Guard (USCG) (2004); US Environmental Protection Agency (EPA) (2004); US National Oceanic and Atmospheric Administration (NOAA) (2003); and the World Underwater Federation (CMAS) (Flemming and Max, 1996).

Requirements for physical fitness testing were considered in four areas:

1. Initial certification
2. Return to dive after illness or injury
3. Renewal of active status after lapse in minimum diving activity
4. Recurrent evaluation

Physical fitness elements were found in various sections addressing swimming skills, rescues and miscellaneous relevant clauses.

Results

Initial certification

Swimming skills for six of the eight reviewed standards are summarized in Table 1. Six specific skills included length swimming, surface kick, underwater swim, treading water/survival float, head-first surface dive, and entry or exit from water.

Swim distances ranged from 219 yd (200 m) to 550 yd (500 m). AAUS (2006) was the only scientific standard incorporating a time component for a surface swim: 400 yd (366 m) in less than 12 min (33 yd·min^{-1}or 30 m·min^{-1}). EPA (2004) offered the option of completing either a 250 yd (229 m) swim or a 440 yd (402 m) swim in scuba gear.

Coast Guard documents provide relevant information regarding physical fitness testing but are considered separately since they are not scientific diving standards. CCG (S. Simms, pers. com.) required a fin swim of 656 yd (600 m) in 15 min (Table 2). The USCG (2004) required a finless 500 yd (457 m) swim in 14 min, completed as part of a continuous sequence with push-ups, sit-ups, and a run (Table 3).

Surface kicking requirements varied from either using snorkels or wearing full scuba gear. The distance obligation ranged from 219 yd (200 m) (AS/NZ, 2002) to 875 yd (800 m) (Flemming and Max, 1996). Surface kick distances for AAUS (2006) and CAUS (1998) were nearly double that of AS/NZ (2002) (Table 1).

Underwater breath-hold swims were without gear for AAUS (2006) and NOAA (2003) standards. EPA (2004) listed a slightly shorter distance but with the candidate wearing scuba gear with a closed air supply (Table 1).

Treading water/floating requirements ranged from 10 to 30 min, with one standard providing an option of two minutes of treading water with both hands remaining out of the water (AAUS, 2006) (Table 1).

A head-first surface dive to 10 ft (3 m) was included in three standards. CAUS (1998) and EPA (2004) required that an object or weight, respectively, be retrieved from the bottom as part of the effort; AAUS (2006) did not specify retrieval (Table 1).

The method of water entry and exit in open water or surf ranged from completing the skill either donning full gear (AAUS, 2006; EPA, 2004) or exiting a boat by using a ladder (EPA, 2004) (Table 1).

Rescue performance was mentioned in five documents (Table 4), although the requirements were vague for AAUS (2006), CAUS (1998) and AS/NZ (2002). The detail provided by AAUS (2006), for example, was limited to 'rescue and transport victim.' Obligatory rescue tow distance ranged from 25 yd (23 m) to 109 yd (100 m). EPA (2004) specified a 25 yd (23 m) tow or 50 yd (46 m) in full scuba gear. Coast Guard requirements for rescue performance were extensive and not reviewed in this paper.

Table 1. Swimming skill standards required for initial certification[1]

Skill	units	CMAS	AAUS	CAUS[2]	NOAA	EPA		AS/NZ
Swim	yd *(m)*	-	400[3] *(366)*[3]	219 *(200)*	550 *(500)*	250 *(229)* or	440 *(402)* in gear	219 *(200)*
Surface Kick	yd *(m)*	875[4] *(800)*[4] snorkel	400 *(366)* in gear	437 *(400)* snorkel	-	-		219 *(200)* in gear
UW Breath-Hold Swim	yd *(m)*	-	25 *(23)*	-	25 *(23)*	17 *(15)* in gear		-
Tread/Float	min	-	10, or 2 no hands tread	20 float	30 float	15 float		10 tread
Head-first Surface Dive	yd *(m)*	-	10 *(3)*	10 *(3)* p/u object	-	10 *(3)* p/u weight		-
Entry/Exit	n/a	-	in gear	-	-	using boat ladder		-

[1] AAUS - American Academy of Underwater Sciences; CAUS, Canadian Association for Underwater Sciences; NOAA - US National Oceanic and Atmospheric Administration; EPA - US Environmental Protection Agency; AS/NZ - Australia/New Zealand Occupational Diving: Scientific Diving

[2] Only one of the four skills listed is required to fulfill the CAUS standard, in addition to a required rescue tow of 109 yd (100 m)

[3] Requirement = 400 yd (366 m) in less than 12 min (minimum 33 yd·min^{-1} or 30 m·min^{-1})

[4] Guideline = 875 yd (800 m) in 16 min (minimum 55 yd·min^{-1} or 50 m·min^{-1})

Table 2. Canadian Coast Guard (CCG) physical fitness requirements[1]
(S. Simms, pers. com.)

Skill	Requirement
656 yd *(600 m)* Fin Kick	<15 min (44 yd/min or *40 m/min*)
40 Sit-ups	2 min
20 Push-ups	Equal rate up and down
5 Chin-ups	Overhand

[1] Minimum standard required for initial certification and annual requalification

Table 3. US Coast Guard (USCG) physical fitness skills to be completed in continuous sequence[1]
(USCG, 2004)

Skill	Requirement
500 yd *(457 m)* Swim	<14 min (36 $yd \cdot min^{-1}$ or $33\ m \cdot min^{-1}$)
10 min rest	
42 Push-ups (minimum)	
2 min rest	
50 Sit-ups (minimum)	
2 min rest	
1.5 mi (*2.4 km*) Run	<12:25 min:sec (8.3 $min \cdot mi^{-1}$ or $5.3\ min \cdot km^{-1}$)

[1] Minimum standard required for initial certification and annual requalification

Table 4. Rescue standards required for initial certification[1]

Skill	AAUS	CAUS	NOAA	EPA	AS/NZ
Rescue Obligation	Self; Diver	Self; Diver at surface and UW	Science divers none[1]	[2]	Diver recovery to surface
Transport	Rescue and transport victim	Accident management and evacuation	Science divers none[1]	[2]	Recovery of diver from water
Rescue Tow	25 yd (*23 m*) person of equal size	109 yd (*100 m*)	Science divers none[1]	25 yd (*23 m*) or 50 yd (*46 m*) in gear	-

[1] Working Diver: rescue skills are covered in a three-week Working Diver course
[2] No distinction between scientific and working divers: rescue skills were to be covered in either a one-week EPA course or a three-week NOAA Working Diver course

NOAA (2007) recently established age- and gender-indexed fitness tests (Table 5). Push-up requirements decreased with age, from a maximum of 37 to 10 for males and from 16 to 4 for females. Sit-up requirements decreased with age from a maximum of 45 to 25, irrespective of gender. NOAA (2007), USCG (2004; Table 2) and CCG (S. Simms, pers. com.; Table 3) were the only standards reviewed that included separate strength/endurance tests in addition to tests of swimming skill.

Table 5. NOAA push-up and sit-up criteria (D. Dinsmore, pers. com.)

Age	Push-ups		Sit-ups
(y)	Male	Female	All
<25	37	16	45
26-30	32	13	40
31-40	25	9	34
41-50	20	6	27
51+	10	4	25

Returning to dive after illness or injury

Physical fitness testing after illness or injury was not formally specified in any of the standards reviewed. EPA (2004) stated that a diver may be asked to requalify or that physical examination may be required 'after a serious accident, injury or illness at the discretion of the [unit diving safety officer].' Several standards required physical examination after any major injury or illness (CAUS, 1998; NOAA, 2003; AAUS, 2006). AAUS (2006) also specified the need for evaluation after any condition requiring hospital care. AS/NZ (2002) allowed for an increase in frequency of examinations at the discretion of the medical practitioner.

Renewing active status after lapse in diving activity below minimum requirements

Physical fitness testing following a lapse of diving activity was not formally specified in any of the standards reviewed. AAUS (2006) left renewal requirements to the discretion of the institutional diving control board. CAUS (1998) did not address renewal. AS/NZ (2002) required divers to complete a checkout program at the discretion of the diving safety officer after a six-month hiatus from diving. NOAA (2003) called for checkout dives and any other requirements prescribed by the unit diving safety officer after a six-week to six-month hiatus, a line office diving officer/fleet diving officer approved requalification program for a six- to 12-month hiatus, and completion of a NOAA Diving Program-approved refresher training program following breaks longer than 12 months. EPA (2004) stated that divers not diving for more than 12 months may be required, at the recommendation of the diving safety board or the unit diving officer, to attend a diver certification course in order to be requalified for diving activities.

Recurrent evaluation

Formal requirements for ongoing physical fitness evaluation were minimal or vague in several of the standards reviewed (CAUS, 1998; AS/NZ, 2002; EPA, 2004; AAUS, 2006). AAUS (2006) required divers over 40 years to complete an exercise stress test during periodic medical evaluation if considered at risk for heart disease. AS/NZ (2002) stated that divers should ensure that they are fit to dive – with fitness being maintained by exercise and regular diving. EPA (2004) declared that divers were to dive only if physically and mentally fit and that they were to maintain a level of fitness compatible with safe diving operations and be willing to retake the swim test any time. CAUS (1998) did not state requirements.

Other standards provided more specific requirements for ongoing physical fitness testing (Flemming and Max, 1996; NOAA, 2003; USCG, 2004; CCG, S.Simms, pers. com.). CMAS (Flemming and Max, 1996) provided the most detail, recommending that divers be able to complete an 875 yd (800 m) snorkel swim in 16 min, and that "…the senior diver in charge should consider the fitness of personnel involved, taking into account the recent diving operations or sporting activities…," and that divers should be given a series of swimming and snorkeling exercises in the weeks proceeding field work if they are unfit. NOAA (2003) required an annual refresher course which included in-water rescues. USCG (2004) and CCG (S.Simms, pers. com.) required divers to successfully complete the initial certification tests annually. In addition, CCG (S. Simms, pers.com) required a recertification course every three years, and declared that divers were expected to maintain fitness compatible with safe diving operations. Divers could be evaluated, and refusal could result in restricted diving activity.

Discussion

The normal demands of diving may well be met by a modest level of physical fitness. Every diver, however, must be prepared to meet exceptional physical demands in emergent conditions. The inability to predict the magnitude of such demands requires preparation for the worst of circumstances, in part by maintaining a superior level of physical fitness. Good physical fitness can improve the outcome of many situations. Successful rescue of self or a teammate may depend on an individual's physical fitness reserve - the difference between any given effort and maximal capacity.

The paucity of recurrent evaluation requirements within the diving community is notable. Programs with military origins demonstrate the most stringent oversight. Those with historical ties to the recreational community, such as scientific diving, mandate somewhat less oversight. The recreational community provides lifetime certification to divers with no recurrent evaluation of skills, medical health or physical fitness. While the scientific diving community addresses medical health with recurrent evaluation, and requires minimum diving activity requirements, programs generally fall short in physical fitness evaluation.

The dearth of physical fitness assessment may have been based on an historic perception that self-governance within the community was adequate. Societal trends, however, suggest that self-governance may not be sufficient. Decreasing levels of physical activity and physical fitness threaten performance capabilities of current and future divers.

The effects of aging are faced by even the most health-conscious of individuals. Maximal aerobic capacity, a benchmark of physical fitness, may decline at an average rate of approximately one percent per year beyond age 25 (Rosen, 1998). While dedicated training efforts may postpone and reduce the rate of decline, a decrement of 0.5 percent per year may still be expected (Marti and Howald, 1990).

Recognition of the age-related decline in physical fitness may have contributed to the recent NOAA decision to adopt an age-indexed performance scale (D. Dinsmore, pers. com.). Practically, an expectation of lower physical fitness in an older versus a younger diver may be compensated for by greater experience, skill and economy. This assumes, however, that the older diver has greater experience. Another societal trend is the pursuit of multiple occupations over a lifetime and delayed retirement. Professionals who are mid-life or later and starting work in scientific diving may not have the accumulated skills of the longtime diving professional.

Physical performance standards should establish at least a minimum capability to complete relevant work. Reasonably, one standard should be applied to all persons. Age- and gender-indexed physical fitness tests do not function in this way. The NOAA (D. Dinsmore, pers. com.) push-up standard, for example, allows a 51st birthday to halve the requirement for males (from 20 to 10). Using a well-established standard for reference (Table 6; Pollock *et al.*, 1978), the NOAA scale requires the youngest individuals to achieve push-up performance classed as 'average' and 'fair' for males and females, respectively. The required performance is 'fair' for both genders in the 50 year old range. The NOAA requirements do not engender faith in the physical preparedness of candidates. The lack of demand for absolute strength in women is most marked. It should be remembered that the strength required to complete a push-up is proportional to mass. Smaller individuals already have an advantage for this reason.

Table 6. Standard values for push-up endurance (Pollock *et al.*, 1978).

			Age (y)		
Rating	**20-29**	**30-39**	**40-49**	**50-59**	**60+**
Men					
Excellent	>54	>44	>39	>34	>29
Good	45-54	35-44	30-39	25-34	20-29
Average	35-44	25-34	20-29	15-24	10-19
Fair	20-34	15-24	12-19	8-14	5-9
Poor	<20	<15	<12	<8	<5
Women					
Excellent	>48	>39	>34	>29	>19
Good	34-48	25-39	20-34	15-29	5-19
Average	17-33	12-24	8-19	6-14	3-4
Fair	6-16	4-11	3-7	2-5	1-2
Poor	<6	<4	<3	<2	<1

Designing tests for initial or recurrent evaluation of physical fitness requires careful consideration. The available standards provide a range of elements to draw from to develop effective evaluation. The most appropriate assessments will create a reasonable approximation of the working environment. Field-based tests are generally most effective. A continuous, serial skill assessment is probably most representative of real-world demands, a concept evident in the USCG (2004) standards. The specifics, however, may fall short of optimal. Allowing a 10 min rest after the swim is inconsistent with the demands of a real rescue situation where one 'skill' after another may be required to succeed in an emergent condition with minimal rest throughout. Immediate transition from one phase into the next may be more appropriate.

Accidents normally manifest when an accident chain - the series of sometimes individually small issues - grows to the point of failure. Testing should present a chain of events that challenge participants and provide reminder that successful efforts to break the chain can render non-events out of situations that could otherwise end in disaster.

Physical fitness testing in open water may be most appropriately administered at the end of a standard working dive, to start the process with a normal level of fatigue. If the dive and physical fitness tests are being conducted strictly for evaluation, the dive phase could include a review of basic diving skills or relevant operational task activity. We propose a test sequence for consideration (Table 7). The specific elements, distances and durations could be accepted or modified as appropriate.

The open water physical fitness test sequence would begin with a 219 yd (200 m) surface swim in full gear (AS/NZ, 2002), followed by a 109 yd (100 m) rescue tow (CAUS, 1998), with both victim and rescuer in full gear. The tow would be followed by an unassisted removal of the victim onto a boat, dock or shore as appropriate for typical operations. Adding to the realistic nature of the simulation, the tow would be accompanied by verbalized decision-making regarding victim management and simulated effort to request aid. The removal would be followed by simulation of basic life support checks of the victim and deployment of emergency oxygen equipment. After deployment of the oxygen equipment, the diver would complete 15 full deflection, military-style push-ups without stopping.

Table 7. Proposed physical fitness test for scientific divers to be completed in continuous sequence.

Open Water Testing Scenario[1]	**Pool Modifications**[2]
219 yd (200 m) surface swim in full gear	328 yd (300 m) surface swim (full gear; no suit)
109 yd (100 m) rescue tow (both in full gear)	220 yd (200 m) rescue tow (full gear; no suit)
Beach/Dock/Boat removal of victim	Poolside removal of victim Victim/Rescuer wear 15 lb (7 kg) weight belts
Basic life support simulation	Same
30 (male) / 20 (female) military-style push-ups	Same

[1] immediately following working dive
[2] immediately following underwater skill drills

The strengths of the above series are the relevance to the normal working environment, the integrated use of standard emergency equipment, and the test of physical capacity. A diver complaining about the relevance of push-ups after completing the rescue can easily be reminded that the need for post-removal evacuation of the victim may reasonably require additional exertion. The point to drive home is the importance of an adequate physical reserve to deal with the any potential demands of an emergent situation. Eliminating the age-indexing on the push-up requirements will certainly be challenging to some, but this is also a component that individuals can easily prepare for independently. Establishing a challenging basic standard can encourage divers to keep track of their fitness.

Field-based tests will not be appropriate for all programs. Appropriate field conditions may not be available in all locations, such as the land-locked home base of a dive team. Seasonal restrictions may also render suitable sites unavailable. For these reasons, alternative physical fitness tests should be available.

Pool tests can provide a convenient environment to evaluate physical fitness. Completing the test scenario in the pool, however, reduces the applicability to the normal working environment by removing some of the natural stressors. The absence of current and minimal wave activity are two examples. Temperate-water divers will also not be able to wear the normal protective suits because of excessive thermal loading. Since a normal working dive will not precede the test scenario, the poolside test could follow a series of underwater skill drills. Where possible, the test should remain relevant to operational diving. Length swimming may not be suitable since it is more of a test of watermanship than physical fitness. While superior watermanship is important and should be promoted, its place is in building or maintaining, rather than evaluating, physical fitness.

The test sequence for the pool could be modified by increasing both the surface swim distance to 328 yd (300 m) and the rescue tow distance to 220 yd (200 m) (Table 7). The poolside removal could be completed with both victim and rescuer wearing 15 lb (7 kg) weight belts in order to partially simulate the load of equipment normally worn or the physical stress of environmental conditions that a diver may experience during a rescue. The weight belts would be donned immediately prior to the rescuer exiting the water and removed after both are on deck. Requiring the rescuer to exit the water using a pull-up, not by using a ladder, would provide a better test of upper body strength (note: the weight belt could only be used with decks close to flush with the water). The standard basic life support simulation and push-up test would follow.

Another option is the exercise stress test, a test that is well established in the scientific diving standards to evaluate divers over 40 years of age if considered at risk for heart disease (AAUS, 2006). While normal physician examination does not evaluate physical fitness, the exercise stress test could be used to assess exercise capacity.

Re-evaluation would reasonably be required on an annual basis in order to establish that physical fitness has not fallen below the minimum standard. An ancillary benefit of scheduled testing is that individuals will have additional motivation to maintain their physical fitness. Recommendations for maintenance programs should be provided to individuals where possible.

Conclusions

An excellent record of safety has been enjoyed by the scientific diving community. The lack of recurrent physical fitness evaluation, however, is a weakness in the current system of oversight. While alternative forms of evaluation such as clinical exercise stress tests and pool tests should be permitted, the preferred standard would be an open-water field-based test completed as a continuous sequence of skills following a typical working dive. The test sequence proposed in this paper includes a surface swim, surface rescue tow, water removal, basic life support and emergency communications and a final measure of strength and endurance with push-ups. The test sequence can be used to evaluate current physical fitness and skill levels, promote fitness consciousness and provide an opportunity for health and safety-related dialogue within the community. Each of these elements is believed to be important to ensure continued readiness and responsible oversight.

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