

REPORT OF A SCUBA DIVING TRAINING COURSE FOR PARAPLEGICS AND DOUBLE LEG AMPUTEES WITH AN ASSESSMENT OF PHYSIOLOGICAL AND REHABILITATION FACTORS

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ABSTRACT

Six severely disabled men were selected for their swimming ability and physiological suitability for diving. Four paraplegics - T4, T6, T12, and L3, and two double leg amputees, one with both legs amputated above the knee, one with one above and one below. The three high lesion paraplegics and the more severe double amputee were normally mobile only in wheelchairs. Medical history and present physical status is presented for all trainees. A daily report is given of a five-day acquaintance diving course during which the trainees completed all the normal scuba pool training schedule as required by the Confederation Mondiale des Activites Subaquatiques and the British Sub Aqua Club. The course concluded with trainees diving in the open sea. It is concluded that self-contained diving training is an excellent rehabilitatory activity for disabled people with the following limitations: no paraplegic should dive in the sea with a lesion above T5; no paraplegic whose injury was caused by bends should dive at all; no disabled diver should undertake decompression dives. Certain general limitations should be applied to weather conditions, etc. Recommendations are made for further training courses, and for supervision of disabled people in diving schools and clubs.

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DIVING TRAINING FOR THE SERIOUSLY DISABLED

INTRODUCTION

Since the 1940s it has been recognised that sports offer to disabled people a unique opportunity to improve their health, enjoy themselves, and achieve social participation and acceptance. Since the inception of the Stoke Mandeville games by Sir Ludwig Guttman in 1948 this aspect of rehabilitation has received public recognition all over the world.

Because of the institutional background of hospital life, and the need to supervise many subjects with few instructors, it is natural that emphasis has usually been on team games and competitive games. These games have also, in western culture, been granted great respect, so that disabled people acquired social integration by playing such games, and particularly by winning. Less attention has been paid to the more solitary sports, characterised in the extreme by the rugged individualist climbing Mount Everest. This class of sports included skiing, canoeing, sailing, mountain climbing, diving, pony trekking, camping, caving or pot-holing, parachuting, flying, hang-gliding, gliding, etc. They are sometimes described as 'adventure' sports or 'risk' sports.

In view of the risk entailed in most of these activities, and the outdoor mobile nature which makes supervision difficult, it may seem perverse to encourage people to take part who have already suffered severe injury or disability at least once. However, there is a good case to be made, and this will be put forward fully at the end of this paper. At this point it is sufficient to say that there is a psychological difference between team competitive games and adventure sports, and that people who are attracted to one are often not attracted to the other. Thus, granted that sports

have rehabilitative value, adventure sports reach a new section of the disabled population. The risk element is no higher than with able-bodied people since the essential art of learning these activities is to learn how to maintain the risk within acceptable limits by modifying the techniques and restricting the task attempted.

DEFINITION OF THE PROBLEM

Swimming has long been recognised as a sport of enormous value, though usually restricted to a pool, and we only know of a few examples of seriously disabled people who attempt long distance swims in the open sea.

Several individuals have taught themselves SCUBA diving, but there has been little formal attempt to define standards of diving instruction and diving qualifications so that disabled people may acquire safe diving training.

The United States army has run several courses in Hawaii for soldiers with single and double leg amputations, and we have been informed by an instructor in Guam of a diver who learnt to dive although he had one arm amputated at the shoulder, and the other at the wrist.

At this point we should define what we mean by a seriously disabled person, and what degree of self-sufficiency is aimed at in training. In the context of diving, the amputation of one leg is not serious, because many people can swim well with one leg. There are problems in walking about wearing the equipment, but they are not medical or physiological problems, nor peculiar to diving. The absence of a hand or arm is more serious, since a diver frequently has to adjust his equipment while underwater. However, the problem is one which can be solved by careful supervision and instruction by a good diving instructor, who must judge the safety of the pupil. There is no special medical problem.

The class of disability which we are considering is typified by double leg amputation or paraplegic spinal lesion. The precise limitations of safe diving will be discussed below, but it is obvious that any injury which affects the subject's respiration, sinus, heart, etc. immediately debars him from open water diving.

It is important also to define the competence in diving which we intend the subject to acquire. In 1966 Mr Pritchard in Kenya showed that diving was possible even for a cervical lesion. He dived accompanied by two friends who lifted him into the water, fitted his aqualung, and towed him about underwater. This has enormous psychological value for the individual who enjoys the underwater world, but does not constitute safe diving at an independent level. In the late 60s and early 70s several individual paraplegics found that it was possible to dive, particularly R Head of London, England, who was an active diver for many years with a partial T10 lesion.

The level of competence which we are seeking to achieve is as follows:- the subject is passed as medically fit to dive so that his companions do not have to worry about him. He drives himself to the dive site, looks after his own diving equipment, but may need assistance getting into a boat, and getting his scuba gear fitted in the water. Once dressed he can swim unaided, dive, adjust his equipment, perform all the normal safety exercises, swim in the company of a buddy diver, monitor the progress of the dive, control his ascent, and swim to the boat on the surface. At the boat he will probably require further assistance to remove his equipment and to get back on board. In the event of becoming separated from the boat he could inflate his life-jacket and survive for many hours. This level of independence ensures a high degree of safety, and permits the disabled person to join in diving groups of able-bodied people, to enjoy underwater observation, photography, natural history, or underwater science and research.

MEDICAL AND PHYSIOLOGICAL REQUIREMENTS FOR SUBJECTS

In July 1974 six disabled men were selected from the Israel Defence Forces wounded soldiers rehabilitation programme. The criteria of the medical examination used were the same as those demanded for any person who is to join a diving course. (References: Bennett and Elliott, Miles, CMAS, NAUI, MAC, etc). In addition each case was examined separately taking into consideration the causes of the injury, and the results of the criterion for uninjured people necessitates a completely normal physiological system, central nervous system, ear nose and throat, and sinuses. In short, the potential diver should be very fit.

The examination included a precise medical history (anamnesis) plus a description of the present physical status, as well as the character of the applicant as far as it could possibly be judged. With regard to disabled divers, all the factors mentioned above were taken into consideration, plus the eight following special points:

1. The respiratory system should be completely normal. All the respiratory muscles should be under control, and the spinal lesion not above T5, preferably not above T8.
2. It is of extreme importance that the skin condition of a paraplegic is proper without any injury, kobitus (pressure sores). For amputees, the scars should be completely healed or perfect, meaning at least three months after amputations.
3. The paraplegic should not have any urinary tract infection, and should have full control of urine and bowel movements, with or without artificial aids.
4. Fullest consideration should be given to the personality of the disabled person: he should show self-discipline, with a full knowledge of his own abilities and disabilities. He should be of steady character with the capability of withstanding anxiety and withstanding anxiety and panic. He should also be of a co-operative nature, accepting orders from his superiors without resentment.
5. He should be an excellent swimmer, participating regularly in intensive swimming, including sea swimming.
6. He should pass physical tests and exercises concerned in preparation for the course, and if necessary undergo special physio-therapeutical training.
7. If he is a paraplegic, his disability should not have been caused by a spinal bend (discussion below), nor by arterio-vascular malformation, nor by transverse myelitis.
8. It should be pointed out to persons with partial spinal lesions, from whatever cause, that there is a possibility that diving might make the lesion complete. There is no record of this ever having happened other than with bends cases, but it is a possibility. There are several cases of people with partial traumatological lesions diving with no ill effects.

Description OF COURSE CANDIDATES

CASE A

Date of birth: 1947

Date of injury: 28 February 1969

Injury: Gun-shot wound penetrating the right upper thorax, lung, and lamina of the fourth thoracic vertebra, with laceration of nerve roots on the right side and contusion of the spinal cord.

Status after treatment:

State after decompression laminectomy at level T4-5 (27 February 1969). The bullet during penetration caused intra parenchymal haemorrhage in the upper apex of the right lung and haemopneumothorax, and was operated. A week after operation all X-rays were within normal limits. The patient remained a paraplegic T4.

Medical history:

Before the injury there is nothing to say, and Case A was always healthy.

Present physical status:

Except for the result of the injury is without pathological finding. Lung and heart within normal limits.

Note:

As a result of the high injury it was decided that this person was not fit for sea diving, but he was allowed to participate in the exercises in the swimming pool with full guidance. This was in order to define more precisely the realistic limits for disabled divers. Case A performed most of the exercises correctly, but it was clear that short bursts of intense exercise caused a difficulty in breathing. This was because he was breathing only with the diaphragm.

CASE B

Date of birth: 4 September 1945

Date of injury: 21 July 1970

Type of injury: Gun-shot wound of the chest. Bilateral haemopneumothorax with fracture of sixth rib and scapular. Paraplegia T6.

Treatment: The penetrating wound back left shoulder, and exit wound in the right shoulder. Suction applied twice and after 4 days of tracheotomy, his condition was improved. He was left paraplegic with sensory level of T.6. X-ray of chest and heart within normal limits.

Medical history:

According to the check sheet the anamnesia excluded any illness past or present.

Present physical status:

Blood pressure 70/110. 60 seconds later - 70.
Ears, eustachian tubes, sinus and pharynx, within normal limits.
Chest, good expansion, good alveolar breathing on both lungs.
Heart - rate 70, regular sinus rhythm, within normal limits.
Chest x-ray - normal. State of fractured rib 6th right, slight thickening of pleura in that region.
Paraplegic with sensory level at T6.
Skin on legs healthy without any pressure sores. Good blood supply to the extremities.

Conclusion: Case B passed the acquaintance course successfully performing all the exercises to the satisfaction of the instructors, including one dive to 7 metres in the open sea.

CASE C

Date of birth: 1947

Date of injury: 27 August 1970

Type of injury: Gun-shot wound entered right side of the back vertebra T12, passed through the spleen and came out through the left side of the body.

Treatment: Had a splenectomy.

Status after treatment:

Paraplegic with sensory level L2. Has had several urinary tract infections, but left the hospital in a good condition.

Medical History:

According to the check-up sheet the artamnesia excludes any illness in the past. After the injury always healthy, only occasional urinary tract infection.

Present Physical Status:

Blood pressure - 110/70 Pulse - 60, 80, 70, 60.

Ears, eustachian tube, ear drum, pharynx, within normal limits.

Chest - good expansion, alveolar breathing with both lungs.

Heart - regular sinus rhythm within normal limits.

Neurological - paraplegia with sensory level L2. No sense of position, no sense of vibration, no reflexes in leg, stomach reflex within normal limits, lower epigastrium reflex absent, no feeling in the genital area, no feeling in the sphincters.

Chest X-ray - without pathological findings.

Conclusions: Case C passed the acquaintance course successfully, performing all the exercises to the satisfaction of the instructors, including one dive to a depth of metres in the open sea.

CASE D

Date of birth: 2 November 1947

Date of injury: 10 June 1967

Type of injury: Compression of cauda equina at level III, IV.

Treatment: Decompression laminectomy.

Status after treatment:

Lesion L3-5. State post haemothorax right side, state after rupture of liver (laparotomy).

Medical history:

According to the medical sheet there was no illness before the injury.

After the injury there was paralysis below the knees.

Present physical status:

Blood pressure - 130/8. Pulse - 80, 100, 80.

Ears, sinus, nose, eustachian tube, pharynx, without pathological finds.

Chest - good expansion, alveolar breathing in both lungs.

Heart - Sinus rhythm regular 80. Within normal limits.

Chest X-ray - without pathological finding, lung and heart.

Neurological - paralysis below the knees. With control of sphincters.

Conclusions: Case D passed the acquaintance course successfully and performed all the exercises to the satisfaction of the instructors, including one dive to a depth of 7 metres in the open sea.

CASE E

Date of birth: 20 October 1945

Date of injury: August 1969

Type of injury and treatment:

Amputation above knee right. Rupture and fracture of right hand.

Amputation of left foot.

Medical history:

Medical record sheet shows always healthy.

Present physical status:

Blood pressure - 110/70.

Pulse - 60, 80, 60.

Ears, nose, eustachian tube, sinus, pharynx, without pathological finding.

Chest - without pathological finding.

Chest x-ray - Lungs and heart without pathological finding. A small metal fragment 0.5 cms x 0.5 cms below rib 10 on left side. All scars have healed perfectly and are dry.

Conclusions: Case E passed the acquaintance course successfully performing all the exercises to the satisfaction of the instructors, and made one dive to a depth of 7 metres at sea.

CASE F

Date of birth: 1947

Date of injury: October 1973

Injury and treatment:

Both legs amputated above the knee.

Medical History and Present physical status:

Healthy.

Conclusions: Case F passed the acquaintance course successfully performing all the exercises to the satisfaction of the instructors, including one dive to a depth of 7 metres in the sea.

PHYSIOTHERAPY AND PHYSICAL TRAINING

Medical examination shows whether people have disabling conditions which would prevent them from diving, but even if they are medically suitable they may not be fit in the sportsman's sense of being in training. Diving does require quick reflexes and physical exertion, and fitness is therefore essential. Subjects for a diving course should be able to pull down with 1/8 - 1/5 their body weight on each hand at full arm extension sideways. They should swim regularly, and lead an active life, involving frequent transfers in and out of wheel chairs, or walking on crutches.

If the normal level of physical activity of the subject, and his present physical condition, do not satisfy a physiotherapist or physical training instructor that he is fit to dive, then a course of exercises should be attended for several weeks prior to commencing diving training. This course would involve at least an hour of swimming daily, with bar exercises, walking on callipers, and exercises with weights, punchbags, etc.

DESCRIPTION OF THE DIVING COURSE, JULY 1974

The six subjects mentioned above were selected by the Israel War Veterans Disabled Rehabilitation organisation, and the medical examinations carried out by Yehuda Melamed and Dan Harel. The course ran from July 11-16th, based at Tivon, a small town near Haifa, Israel. A staff of diving instructors, swimming instructors, and physiotherapists was assembled. The essential point is that every disabled subject was accompanied by a diving instructor when in the water in the training pool, and by two instructors, when in the sea. The visibility in the pool was about 3.0 metres, and there was no attempt to run an underwater class, with one instructor supervising several pupils.

Pre-course training

The subjects gathered at the Tivon swimming pool a week before the course and were tested for swimming ability. They purchased masks and snorkels, and practised swimming with them in the pool.

Course routine

It was originally planned that the course should be full-time during the day, allowing a total of 6 hours for lectures and pool sessions each day. Some of the course pupils had to continue studies and exams in the mornings, and thus the timetable was rescheduled to run from 1500 to 1900 or later each day. The pupils thus had a very heavy day's work. Four days of pool exercises and theoretical lectures were followed by one day for diving in the open sea at Akko. Pupils drove themselves to and from the pool and lecture areas, changed into swimming trunks themselves, and in most cases could get in and out of the pool without assistance.

Course syllabus

The course syllabus was based on the British Sub-Aqua Club 3rd and 2nd Class standards, and the training methods of the Israel Underwater Federation.

DAY 1 - Demonstration by disabled instructor (NCF) of the following exercises in the pool:

- (a) Fitting mask and snorkel on pool side and entering water
- (b) Fitting mask and snorkel while swimming
- (c) Duck-dive to 3 metre depth
- (d) Swim 20 metres underwater
- (e) 3 rolls forward underwater on one breath
- (f) 3 rolls backwards underwater on one breath
- (g) Breathing through snorkel without mask, face down in the water
- (h) Fitting scuba set while hanging on side of pool
- (i) Adjusting buoyancy with air-inflatable life-jacket (ABLJ)
- (j) Removing and replacing mask and scuba mouthpiece underwater
- (k) Removing weight belt, mask, and scuba underwater, and free ascent

The pupils then swam 180 metres each on the surface, at a steady pace. The T4 Case A was considerably slower than the others, though the swim was not timed.

The pupils then demonstrated breath-holding and confidence in the water by lying face down floating on the surface for as long as possible. Times, without hyperventilation, were as follows:

Case A - 35 secs	Case B - 1 min 42 secs	Case C - 1 min 35 secs;
Case D - 1 min 20 secs;	Case E - no test;	Case F - 28 secs.

Pupils hung on the side of the pool and breathed through snorkel without wearing a mask for one minute. All adapted successfully with the exception of Case A, who had to continue practising. All pupils then swam 20-30 metres submerged on a single breath, with times varying from 20-40 seconds.

Pupils then demonstrated forward and backward rolls underwater equipped only with mask and snorkel. All pupils achieved 3 rolls on one breath, with the exception of Case A who could only do two. It was clear that, although very competent and self-possessed in the water, this exercise required greater breath control and inhalation than could be achieved using the diaphragm alone.

Pupils then practised fitting mask and snorkel while swimming or floating in the pool. For a paraplegic, or double amputee without fins, this is much more difficult than it sounds, since the act of raising the hands out of the water causes the body and the head to sink. The most effective technique was as follows: the pupil duck-dived to 3 metres and picked up the mask and snorkel from the bottom. The snorkel was then tucked into the side of the swimming trunks while the mask was fitted. Since the head and the mouth sank into the water during mask fitting, breath-holding was required, and the mask was inevitably full of water. As soon as the mask was sealed the pupil breathed through his mouth, swimming with one hand, while he recovered his snorkel. The snorkel was fitted while breathholding again, and then the mask could be cleared of water by inhaling through the snorkel and exhaling into the mask. Most pupils made several attempts before succeeding in this test, and Case A found it very difficult because of his difficulty in preventing inhalation through the nose.

During this pool session pupils were in the water for nearly two hours, most of that time being actively devoted to exercises, and part of it hanging on the side. Because of the effort involved getting in and out of the pool, pupils tended to keep this to a minimum. Several pupils scratched or grazed their legs, in spite of frequent warnings. In subsequent sessions all paraplegic pupils wore elastic athletic bandages around their knees, and a canvas pad was arranged on the side of the pool in the corner.

Lectures before and after the pool session included the following topics: Mobility for the disabled diver; physics of diving; liquid laws (Boyle's Law, Charles' Law, Dalton's Law, Henry's Law); outline of the physiology of diving; respiratory system; dangers of hyperventilation and incorrect breathing.

DAY 2: The pupils spent 25 minutes in the pool repeating the exercises learnt on Day 1. To test confidence and sense of direction, all pupils then swam one length on the surface with the mask completely blacked out.

This was followed by a 45 minute lecture at the pool-side on the following subjects, with demonstrations: adjustment of ABLJ, filling and fitting ABLJ cylinder, buoyancy adjustment while diving, breath control, principle of breathing regulator, fitting regulator to tank, testing tank pressure, importance of exhaling during ascent, hand signals.

The pupils all filled their own ABLJ cylinders from their scuba tanks, and entered the water for their first exercises with scuba equipment. In each case the pupil entered the pool at the corner wearing mask, snorkel, and ABLJ. The scuba set was lowered beside the pupil as he hung on the rail, and the instructor helped the pupil to fit the set and adjust the harness. With an inflated ABLJ the pupil could fit the scuba gear without help. Two or three pupils were in the pool at a time, each with an instructor. The pupils dived to rehearse hand signals, and then performed the following tests: two lengths of the 30 metre pool submerged on scuba; rolls and loops to demonstrate attitude control; buoyancy control by breathing; clearing the mask of water.

Performance was very variable. Case A was good on swimming and hand signals, but could not clear mask; Case B was so confident that he took off his mask completely several times and exchanged masks with his instructor while submerged; Cases C, C and E performed well; Case F was confident and successful, but had difficulty in maintaining a balanced attitude in the water.

Each pupil was submerged for 20-30 minutes on scuba. Although they wore ABLJs they were not permitted to adjust buoyancy themselves for the first day, to avoid the danger of over-inflation and rapid ascent. The instructor adjusted the buoyancy as needed.

There were no lectures on this day.

DAY 3: In the pool training all pupils dived first to rehearse the lesson of the previous day. After assembling and donning their ABLJ and scuba gear they performed the following tests: rolls forward and backwards; remove and replace regulator mouthpiece; remove and replace mask underwater. Pupil A was submerged for 16 minutes but could not succeed in mask clearing; the other pupils completed the tests in times as follows: B - 16 minutes, C - 9 minutes, D 9 minutes and E - 14 minutes. Pupil F had extreme difficulty in getting his attitude trim balanced, and worked closely with an instructor attaching weights on various positions on the torso until stability was gained. This was achieved by fitting weights to the ABLJ at the upper chest level. Pupil F was submerged for 18 minutes.

A pool-side lecture and demonstration was then given on the following topics: operation of the ABLJ, control of ascents, effect of wearing a diving suit, effect of pressure on buoyancy of suit and ABLJ, effects of work, cold, and depth on rate of air consumption, variations in breathing resistance with depth and tank pressure. There was a demonstration of the correct order of donning equipment.

All pupils then dived with their instructors in the pool and carried out the following exercises: submerge and share the scuba mouthpiece breathing alternately with the instructor for several minutes; swim one length submerged, surface, change to snorkel, and swim one length on the surface; swim one length underwater with a blacked-out face mask. All pupils completed these tests successfully.

In the evening there was a lecture on the following topics: physiology under pressure; effects of the various gas laws as they apply to the gas spaces of the body; Dalton's Law and the various kinds of gas poisoning, oxygen, nitrogen narcosis, carbon monoxide, carbon dioxide, and hydrocarbon gases.

This was followed by a lecture on mobility for disabled people on diving expeditions, including methods of crossing rough ground, negotiating steps, camping, and living rough.

DAY 4: The course gathered at the pool to practise the advanced exercises of fitting and removing complete scuba gear while submerged, and life-saving. It was explained that removing scuba gear underwater was possibly useful in certain kinds of emergency, and that donning equipment underwater was relevant to changing sets for prolonged decompression, etc. However, it was made clear that the principle reasons for these tests was to show complete control of the equipment by the pupil, and complete confidence underwater.

For removing equipment the pupils were instructed to proceed as follows: sit on the bottom, remove weight belt and place it across the legs, unfasten scuba harness and slip off one shoulder strap, swing tank round and slip off the other shoulder strap, pull tank down beside diver and lay it on the bottom so that the regulator is close to the diver, remove mask and snorkel and place them on the bottom, start to turn off the tank pillar-valve, take one large breath and close the tank completely, ascend slowly exhaling all the time.

For fitting equipment underwater all the gear was thrown into 2-3 metre depth with the tank pillar-valve turned on, and the regulator mouthpiece tucked under the weight belt to prevent free venting. The pupils were instructed to proceed as follows: swim down, pick up mouthpiece and start breathing, take weight belt off tank and place across legs while sitting on the bottom, pick up mask, fit and clear it, pick up tank, slip one arm through harness, swing tank round behind back or over the head, put other arm through harness, fasten waist buckle, fit weight belt, swim one length submerged,

surface slowly.

It was explained that the second exercise was much more difficult than the first. Pupils must complete the first exercise to qualify for a sea dive, but would not be disqualified if they failed to complete the second. For paraplegics with no control of their waist muscles it should be appreciated that both exercises require an extremely acute sense of balance, and continuous slight hand movements to prevent the diver falling over. NCF then gave a demonstration of fitting the equipment underwater using the technique as instructed.

The pupils then carried out exercises as follows:

- A - Had not achieved sufficient control to attempt these tests. Was given intensive instruction in breath control, balance, and mask clearing. Improved rapidly.
- B - Removed equipment swiftly and calmly. Had trouble with balance during fitting equipment, and instructor held legs down to improve stability. Completed both tests.
- C - as for B, but could have completed exercise without help
- D - as for B
- E - both exercises completed quickly and calmly without any help
- F - both exercises completed quickly and calmly without any help

Pupils B - F were very enthusiastic about these tests, and carried them out several times in order to improve their efficiency. The instructors then demonstrated life-saving with each pupil in turn, bringing them to the surface and towing them one length of the pool. The pupils were shown that they could assist a diver in difficulty by releasing his weight belt and/or inflating his ABLJ, but these exercises were not practised.

In the evening there was a lecture on the following topics: structure and function of the sinus, ear, eustachian tube, ear-drum; circulation and respiration, function of alveoli, risks of embolism and blocked alveoli, dangers of heat loss and exhaustion; dive planning.

This was followed by a lecture on methods suitable for disabled people getting from the shore onto diving boats, in and out of the sea from various kinds of beach and foreshore, and from boats into the sea and out again.

DAY 5: The class and instructors met at the quay-side in the harbour of Akko at 0715. The early hour was chosen to try and avoid the wind which gets up during the day. After careful consultation and discussion YM and NCF had decided that it was not safe for A' to dive in the sea with scuba tanks. While he undoubtedly had excellent mental and emotional adaptation to diving, the height of the lesion at T4 made diving dangerous anywhere except in a pool under supervision. At 0750 the first pair of pupils, B and F boarded the 8 metre diving boat, accompanied by diving instructors, a doctor (YM) and physiotherapists and observers. In a water depth of 8 metres the boat was anchored, the pupils lowered themselves over the side, and the instructors helped them to fit scuba gear in the water. Each pupil dived in the company of two instructors, and the visibility was less than 3 metres. They were submerged for 20 minutes, and then returned to the boat. F was able to get from the boat into the water and out again unassisted, but B required assistance.

The boat returned to shore, and the personnel were exchanged so that the other four course members could put to sea. Pupils C and E carried out the same dive as the first pair, in a slight wind with a half metre swell. Pupil D dived last, by which

time, nearly 1000, there was a strong breeze and waves of about 1.0 metre. Pupil A snorkelled safely for about half an hour, but did not dive.

On July 22nd 1974 pupils A, C, D and E gave a demonstration of diving at Beith Halochem Sports Centre for the Disabled, near Tel Aviv. The pool was 50 metres long with excellent clear water, and the demonstration was documented with underwater photographs and underwater television. An audience of several hundred watched the demonstration at the pool, and the participants were presented with certificates recording their achievements.

DISCUSSION

Effectiveness of the course

The course described above was designed as an acquaintance course to demonstrate that seriously disabled people could master the techniques of scuba diving in safety, and to establish the best methods of diving and instruction. The progress of the course has been presented in detail since authorities wishing to follow or improve upon this example will naturally be very cautious, not to say sceptical, and it is therefore important to provide exact evidence of the progress of a group pupils. The question of further training will be discussed below.

Maximum degree of injury permissible

This problem has already been discussed in the section on medical criteria, but is considered here from the point of view of safety on a dive in the open sea, rather than from a purely physiological standpoint. It has been demonstrated clearly that T4 paraplegic lesion prevents diving in the open sea. Whilst pupil A showed the greatest courage, self-control, and competence in the water, the loss of respiratory muscles was critical. In contrast, pupil B with a T6 lesion was completely safe. This confirms the theoretical prediction that T5 is the highest lesion which can be permitted diving in the present definition. Any pupil with a lesion above T8 should be scrutinised especially carefully.

The most serious problems of safety related to attitude control in the water, and the restrictions resulting from the hands being required both for propulsion and adjustment of equipment. The paraplegics had good attitude control when swimming, though the feet tended to float up a bit, but had some problems with the advanced pool tests because of the lack of waist muscle control. Conversely, the double amputee with both legs off above the knee had difficulty in controlling the attitude when swimming with scuba, but had no difficulty when swimming with scuba, but had no difficulty when sitting on the floor of the pool. Pupil F found it necessary to attach weights at waist level to attain a good swimming attitude with tanks.

A special danger for paraplegics is that they do not know the position of their legs unless they look at them. This is quite difficult while wearing mask and scuba, and so there is the risk that their feet or knees will collide with rocks, coral, or wreckage. If complete suit covering is worn there is no risk of abrasion or cuts, but in the absence of a suit, extreme care must be maintained.

Special consideration has been given to the situation of paraplegic lesions, or other types of paralysis, arising from bends. The conclusion quite simply is that *a person who acquired a paralyzing disability as a result of bends should not dive again*, and this applies to a spinal or cerebral bend even if a cure is achieved through recompression treatment.

Discussion with Dr HV Hempleman and Dr HL Frankel produced the following evidence. A spinal bend damages the spinal cord as a result of interrupted or reduced blood supply. Recompression treatment, or the restoration of blood flow. However, there is no means of knowing whether the capillaries have truly been restored to their normal efficiency. Neurological tests of reflexes etc. will confirm that the spinal cord is functioning adequately at normal atmospheric pressure, but there is no means of discovering whether the blood supply would remain adequate under extreme stress, pressure, or unusual respiratory conditions, other than by exposing the subject to risk in those conditions.

The recent cases can be quoted to illustrate the risk. Subject X was diving in the Channel Islands, acquired a bend, and was brought to Stoke Mandeville Hospital paralysed after recompression treatment which failed to bring any improvement. After ten weeks of complete rest and care X began to recover sensation and muscle control in the lower part of his body, and eventually walked out of hospital completely fit. A few months later X was swimming in a pool, and attempted to swim a length underwater whilst holding his breath. He was paralysed again and was returned to hospital. After a further few weeks he recovered sufficient strength in his legs to walk with the aid of a stick, but four years later he still walked with a serious limp, and required a stick for support.

Subject Y was diving daily to 35 metres in the North Sea, and acquired a bend which paralysed him from the waist down. He was treated immediately with recompression, and apparently recovered completely. Several weeks later he returned to diving with scuba, and two months later was diving at 25 metres on a no-stop dive. After ascent he was paralysed again, from the lower chest down. Recompression treatment failed to produce complete alleviation of symptoms, and for several months he experienced numbness in the legs, headaches, and abnormal reflexes a year later there were still slight residual symptoms.

These cases demonstrate that inadequate decompression causing spinal damage can result in a condition which is undetectable by neurological examination, but which is extremely dangerous. Quite apart from the fact that a person who has suffered one Type II bend may be prone to such bends, the first exposure, whether partially or totally cured or not, may have left damage at a higher spinal level with no neurological symptoms. Upon a second exposure the subject may be very seriously injured.

Optimum Training Schedule

The course at Tivon/Akko was designed as an intensive acquaintance course. It was successful because the pupils had been selected as having exceptional aptitude, in spite of their disabilities, and there was a large team of skilled instructors. There were doubts on the first day as to whether the course members could stand the pace of two hours in the water and two hours lectures as the second half of a working day. In practice the pupils showed increasing enthusiasm and no adverse effects. However, the course was excessively intensive, and people with less innate aptitude are capable of becoming competent divers. In general an introductory course should be more gradual and less intensive.

An optimum introductory course, with a view to subsequent continuous diving training, might consist of 5-10 trainees, supervised by a doctor, 2-3 physiotherapist/swimming instructors, and 3-5 diving instructors.

The course would last 3-5 full days, including 2 hours of lectures, demonstrations, films, technical displays, etc for each hour actually spent in the pool. There should be ample opportunity for reading and studying, discussion with the instructors, and trainees to form a single social group. Each disabled trainee has special difficulties and problems arising from his injury, and the instructors will be learning how to cope with this, as much as is the trainee. This requires the instructors to understand and identify themselves with the trainees to a very high degree.

Optimum follow-up and progressive training

When the standards of training for disabled divers have become well established it may be possible, and preferable, for trainees to join diving clubs or diving schools immediately after their medical selection, and receive training from qualified diving instructors in the usual way. In the mean time it is preferable that severely disabled people in the categories considered here should receive initial training at special short courses supervised by doctors and physiotherapists. Such courses could be established in many countries by co-operation of national sports diving organisations such as NAUI, BSAC, FFSSEM, and the veterans administration, and disabled sports organisations.

Disabled divers should not dive with each other. After receiving initial training, the trainee should join an active diving club or diving school. Training in these organisations is usually carried out on a part-time basis over many weeks or a few months, and this is ideal for the disabled person. By diving regularly with members of the club or school the disabled diver will acquire a group of friends and fellow divers who know his capabilities and limitations when diving at sea, and this will provide maximum safety.

Disabled divers should as far as possible complete all the established training exercises as laid down by the Confederation Mondiale des Activites Subaquatique, and be granted the appropriate certificates. The CMAS standards of training should only be reduced or modified to allow for restricted depth and sea conditions, as discussed below, and in respect of life-saving, since the disabled diver can give very little assistance to others. The disabled diver who acquires sufficient sea experience to become qualified should receive a certificate or log book endorsement stating clearly the limiting conditions within which he may dive safely. He should receive an annual medical check to ensure that it is safe to continue diving.

Performance limitations and dive planning

It is hoped that the present article will be used by diving clubs and disabled sports organisations to help them assess the suitability of disabled diving trainees, and to plan diving trips including disabled people. It is important therefore to try and visualise the full performance envelope of a disabled diver, showing the weak points, and the means of compensation.

Table 1 is a very subjective attempt to estimate the relative level of competence which may be shown by a disabled diver compared with an average trained sports diver. The figure of 100 is taken to represent the normal competence, safety level, etc for the average sports diver.

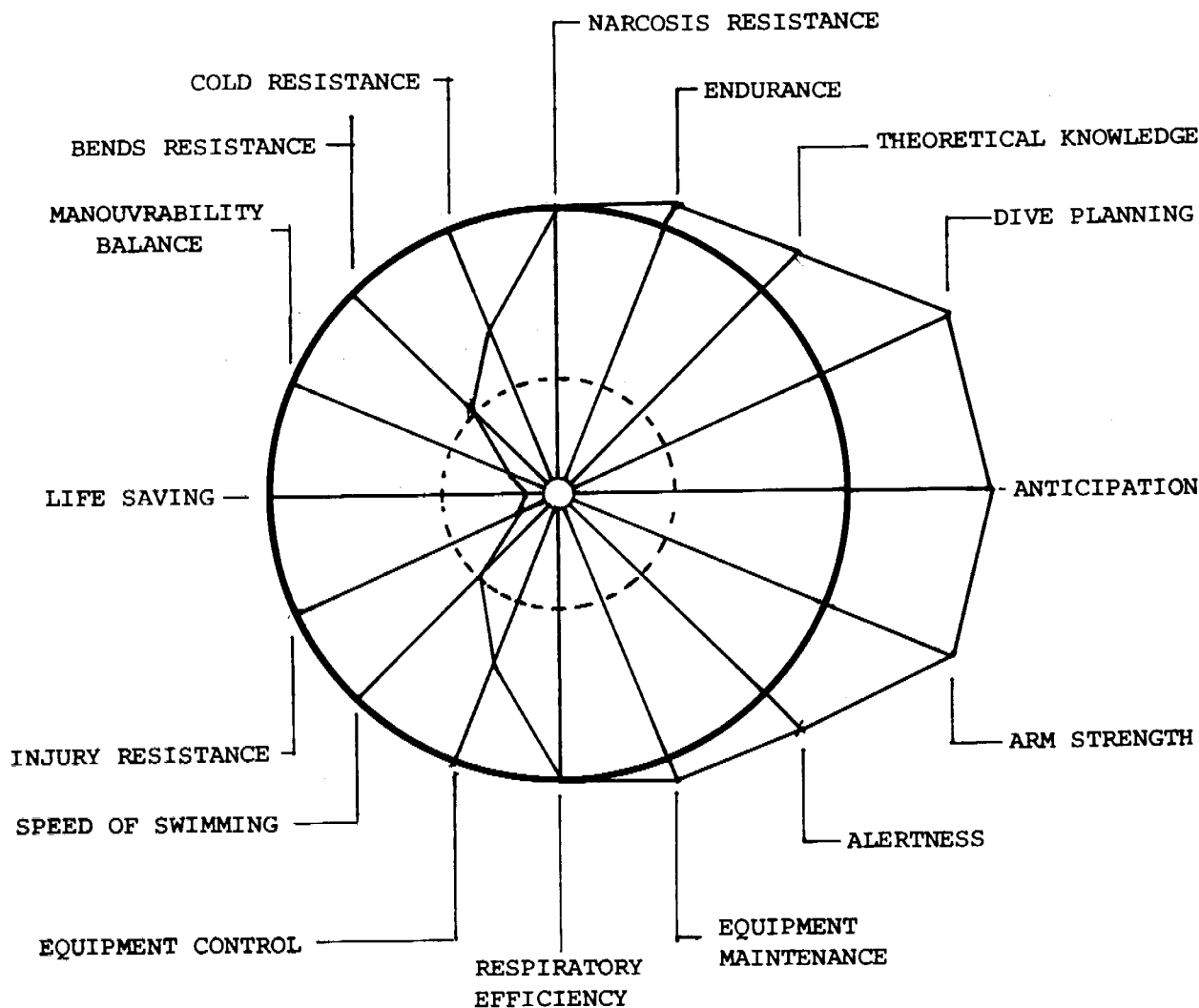
Paraplegics may tend to get cold more quickly than able-bodied divers, and should wear additional protection. This will vary between individuals very much. If a

paraplegic becomes very cold during diving, do not try to warm him up with a very hot bath, as this may cause burns. The hottest bath that is safe is about 40°C.

TABLE ONE

<u>Performance losses</u>		<u>Performance improvements</u>	
<u>AVERAGE SPORTS DIVER = 100</u>			
Life saving	10	Dive planning	140
Manoeuvrability/balance	30	Anticipation	140
Injury resistance	40	Arm strength	130
Speed in water	50	Alertness	120
Bends resistance	50	Equipment maintenance	120
Cold resistance	70	Theory knowledge	120
Equipment control	70	Endurance	110
Narcosis resistance	100	Respiratory efficiency	100

FIGURE 1



BASIC RULES FOR SEA DIVING BY DISABLED PEOPLE

The following rules are based on six years of disabled diving experience by one of the authors (NCF) and the conclusions from the course in Israel.

1. Obey all usual diving regulations and medical regulations concerning diving.
2. Your safety factor is always lower than for an able-bodied diver.
3. The dive begins when you leave home and ends when you get back home safely.
4. NEVER DIVE ALONE.
5. ALWAYS DIVE WITH TWO ABLE-BODIED EXPERIENCED DIVERS CLOSE TO YOU IN THE WATER; THAT IS WITHIN 5 METRES OR VISIBILITY RANGE WHICHEVER IS THE SMALLER. THERE MUST BE AT LEAST ONE DIVER IN THE COVER BOAT AND A BOATMAN.
6. Always plan and survey your entry into and exit from the water with the people who will be helping you.
7. Make sure that your diving companions know your limitations in terms of diving safety, and general medical care.
8. You cannot use your hands to adjust your equipment or carry out work while you are swimming. Avoid situations which require both at once.
9. Never dive in a current stronger than you can swim against for a long time.
10. Avoid abrasions and cuts from reefs and rocks. Do not touch corals.
11. Do not make dives requiring decompressions stops.
12. Never go under overhangs.
13. Never go inside caves or wrecks.
14. Never dive at night.
15. Never dive in visibility less than 3 metres. It is impossible for your companions to stay sufficiently close to you to give rapid help in these conditions.
16. Never dive in waves of more than 2 m (?) or a strong wind.
17. Plan all diving operations with multiple redundant safety measures and fail-safe procedures.

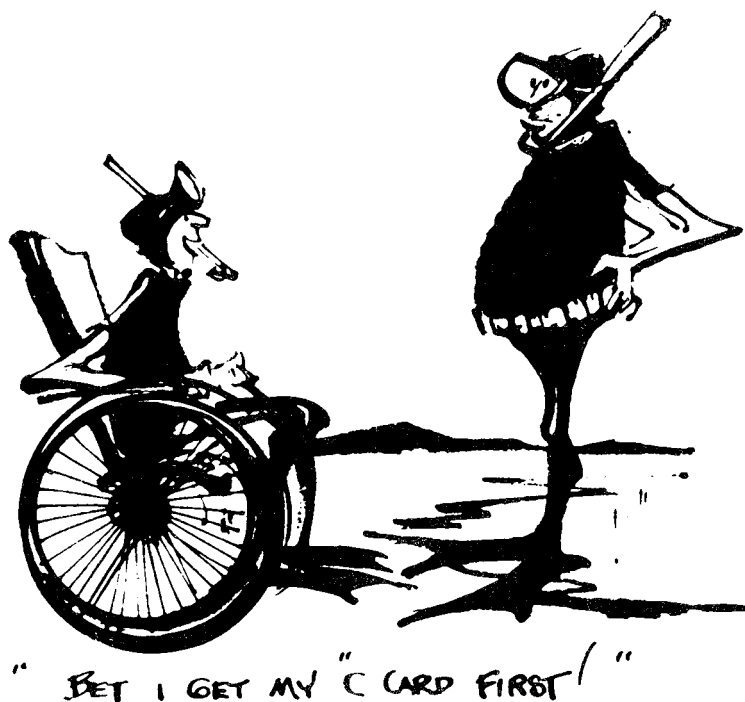
VALUE OF DIVING FOR DISABLED PEOPLE

It has long been recognised that swimming is an ideal sport for disabled people, since it enables them to discard all artificial aids to mobility and to obtain a maximum level of exercise enjoyably. While swimming gives the disabled person free mobility in two dimensions, diving gives the third dimension. The disabled diver can swim, rise, or descend, roll and turn in any attitude, with no special equipment other than

conventional diving gear.

As pointed out at the beginning of this article, risk sports, or adventure sports, appeal to a different mental and emotional character than do team competitive sports. Team competitive sports require superlative performance within the limits of arbitrary man-made rules; the goal is competitive victory over the opponent. It is most unlikely that the disabled person will be able to compete with able-bodied people because he would always be beaten. Adventure sports are not competitive, although they can be made so in some cases, and the goal is to use skill, judgement, and strength to live with and overcome a natural environmental situation: the air, the sea, a sheer cliff, a glacier.

Quite apart from the satisfaction of mastering a difficult technique, a dangerous environment, and obtaining enjoyable physical exercise, diving - in common with some other adventure sports - requires intense group cohesion, loyalty, and mutual trust. A solitary diver is always unsafe, whether disabled or not, and divers learn to depend on each others' skill and ability for their physical safety. This applies to planning, equipment maintenance, and training, as much as to actual co-operation during buddy dives. Involvement in the overall planning and preparation for dives means that the disabled person should become completely integrated into the team. Even in cases where a person is so severely disabled that it is not safe to dive at sea, it is possible



the sufficient enjoyment and exercise may be obtained in a pool to justify the effort.

ACKNOWLEDGMENTS

The paper on the Israeli paraplegic divers was first presented at the Diving Officers Conference of the British Sub-Aqua Club in 1974. The paper by Culp and Lobel first appeared in Sea Frontier, the bi-monthly magazine of the International Oceanographic Foundation. Our thanks are due to these organisations for help in allowing

republication.

APPENDIX A

BRITISH SUB-AQUA CLUB DIVING OFFICERS CONFERENCE

Guidance for Branch Diving Officers on the Possibility of Diving Training for Disabled People

6 November 1974

INTRODUCTION

Early in 1974 there was a meeting between the Minister for Sport and the Minister for the Disabled, as a result of which the Sports Council has set up a number of liaison groups between sporting bodies and various groups representing disabled people. The aim of this scheme is to permit disabled people to join normal sports clubs, and to participate in outdoor activities. Reg Vallintine represented the BS-AC at the first few meetings until, about midsummer 1974, I was appointed the official BS-AC representative on the Sports Council Committee for Water Sports for the Disabled.

In spite of the strict necessity for medical fitness in diving, it has long been apparent that a person with quite a serious injury, say one leg amputated above the knee, could become quite a competent diver, other things being equal. Several more seriously injured people have taught themselves to dive, and in about 1968 Bob Head, a paraplegic with both legs almost completely paralysed, joined London Branch. Keith Nicholson was then Diving Officer, and he decided to accept Bob for training, using his experience of diving safety to judge what could and could not be safely attempted by a person with this disability. Bob became a competent and keen diver, with many sea dives to his credit, though he has recently cut back on his diving in order to take up flying aircraft!

In 1969 I became paralysed from the waist down as a result of a car accident, a condition known medically as paraplegia. From 1970-73 I worked slowly and steadily at exploring the full possibilities for disabled diving, sticking as closely as possible to the full BS-AC training schedule and tests. In 1974, as a result of negotiations by BS-AC Vice President Alex Flinder, I compiled a diving training course for seriously disabled men. The attached report is a preliminary version of a paper which I have written together with Dr Yehuda Melamed, which we hope will be published soon in the journal *Undersea Biomedical Research*.

The policy of the BS-AC is to encourage branches to accept disabled members for diving training wherever possible, entirely at the discretion of the Branch Diving Officer. The attached report should demonstrate that disabled people can be safe divers, and active branch members, provided that the proper medical precautions and checks are made first. If a seriously disabled person comes to you and wants to learn to dive, give him a copy of this paper, and ask him to take it to his GP, and your branch diving doctor, so that the doctor can establish the basic feasibility of the person taking up diving. Once that has been done it is up to you, the DO, to decide if the candidate is suitable. To put it in its most direct terms, if a man is going to make a safe diver in a disabled condition, he would have been a very good diver when he was completely fit.

There is no reason why a disabled diver should be a passenger in the branch, and you can always clobber him for equipment maintenance, treasurer, social organisation, fund raising, editor of the Branch newsletter, etc.

If half the branches of the BS-AC enrolled one disabled person each and taught him or her to dive, that would be a fantastic achievement. Please write to me if you have any questions.

NC Fleming

NSW Branch Scientific Meeting - 5 March 1977

The members who attended this meeting were treated to an interesting and varied program, the result is large part of the determined efforts of Dr Chris Lowry. The setting was the Old Stone Building lecture room at the Prince of Wales Hospital. This choice of venue loses nothing from its proximity to a pleasant and historic hostelry and is commended for future meetings.

The first speaker was Dr Doug Walker, who tried to persuade the audience that a fresh look was needed in the realm of Medical Standards. He instanced the cases of applicants with histories of asthma, diabetes, spinal Bends or even traumatic paraplegia. Individual consideration rather than inflexible rules were advocated. The fallibility of the resting ECG in predicting future coronary thrombosis was noted, quoting aviation medicals in Australia over a recent 10 year period. The overwhelming importance of good training and correct diving routine as the most important safety factor was stressed. Next Dr Bart McKenzie spoke on sinus barotrauma, mentioning that 25% of cases were associated with ascent and warning that facial numbness could result from antral reaction effecting the nerve directly and need not indicate a CNS lesion. The diagnosis naturally considerably effects therapy!

We were privileged to hear Dr Yeo describe the recent work at the RNSH Spinal Unit, using sheep, concerning the use of HPO to reduce the damage after spinal injury. The results justify further work and in fact some patients have received treatment. It was suggested that possible repeated treatments would be even better than a single one, the mode of the initial sheep experiments. The supposed reason for benefit from HPO was by helping tissues near to the primary damage retain viability despite the bruising and reduced circulation. That HPO can itself produce toxic effects was mentioned by one member. It was noted that in the elderly a central cord lesion could very easily follow a minor fall. It was suggested that any casualty where cord damage was suspected should be given mask oxygen therapy from the earliest time seen and transported with continued oxygen.

Professor Colebatch was our second "special". He described his recent work on divers who had suffered pulmonary barotrauma not due to apparent failure of ascent techniques. He related the damage to the abnormal elastic forces in the lungs of such people, an abnormality not effecting routine tests of respiratory function. Both Professor Colebatch and a member of the audience described the occurrence of pulmonary barotrauma in people attempting too vigorously to excel at ventilatory tests! The damage occurs, logically but possible unexpectedly, on the INSPIRATORY effort phase. Cases where the barotrauma occurred associated with ascent technique failure have been shown to have normal elastic forces in their lungs.

Mr John Pennyfather gently but firmly let us see that the problems of diving at altitude were complex: we could see why those in need of advice came to him. In answer to a query about flying after diving he gave two instances worth serious consideration. The first concerned a saturation diver in the USA who suffered Decompression Sickness five days after surfacing, due to taking a plane trip. In the other instance, five RAN divers went on a bus tour in the Canary isles, to an altitude of 7,000 feet, after diving that day and the one previously: they suffered "bends" also. As he said, there appeared to be little basis for the accepted rule of 12 hour delay between a dive and flying. One possibility is that ascent from sea level merely makes apparent the subclinical decompression problem in such people. Once more we must accept the limited safety given by our present level of understanding of decompression problems.

Dr John Knight brought us back from the clouds to the practical dangers of entering cold water. In one instance in Victoria an experienced diver only survived his entry because his demand valve was already in his mouth; the sudden cold-reflex inhibition of control of respiration made it quite impossible for him to take voluntary action. Had he needed to surface in order to take a breath he would inevitably have drowned. Dr Knight also reminded the audience that body core temperature continued to fall for perhaps half an hour after removal from the water, and full return to a normal core temperature could require two hours or more. Heat loss in water is delayed in onset but not changed in ultimate extent by normal wet suits, heat loss being greater in the active than the static: the fact that 71% of the human body is within 2.5 cms of the skin surface makes the peripheral vasoconstriction important in heat conservation.

The final talk was by our President, Dr Ian Unsworth. Two case histories were presented to indicate that HPO therapy can be beneficial even after a delay of several hours from the incident of cerebral air embolism. Neither of these cases were initially recognised as being examples of this condition, and in neither case was the necessity for HPO as a primary mode of treatment recognised immediately. The first case was associated with an anaesthetic incident, the second with a childhood misadventure. Despite a delay in initiating HPO of 20 hours, the recovery was ultimately complete in the first case. Naturally diagnosis is easier in retrospect than under clinical stress but the existence of a hyperbaric facility makes diagnosis important.

The meeting was a success. The report is full so that the many who almost came will gain some benefit also.

