Children and diving: medical aspects. Eight years' sports medical follow-up of the first scuba diving club for children in Belgium

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Key words
Scuba diving, children, medicals/diving, incidents, accidents, ENT

Abstract
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Evaluation of prospective paediatric divers has been based largely on opinion, with limited data. Two hundred and thirty four children aged six to 13 years wishing to scuba dive were enrolled in a prospective study of diving medical evaluation between 1985 and 1992. Medical evaluations, including pulmonary function testing, and resting and exercise ECGs were performed annually by one physician. An electroencephalogram (EEG) was performed as part of the initial examination. Twenty-nine children (12.4%) were excluded: 12 (5.1%) did not complete the initial medical assessment, 12 (5.1%) had abnormal EEG patterns, four (1.7%) were asthmatic and one had sickle cell anaemia. In the remaining 205 children, Eustachian tube dysfunction (12.2%), wax build-up in the external ear canal (5.4%) and otitis externa (3.9%) were the commonest problems during the pool training. All these incidents were minor. Five accidents (2.4% of qualified divers) occurred during the swimming pool sessions, all with full recovery. Four of these were tympanic membrane perforations, two in the same child, and all during the first year of the programme. One potentially life-threatening accident was a breathhold hypoxic syncope in a twelve-year-old. No incidents or accidents occurred during the 2216 open water dives completed in the study. The average follow-up was five years. No subsequent developmental problems, with special focus on growth, pubertal development and hearing, were seen. This study provides evidence that scuba diving may be successfully and safely undertaken in the eight- to 14-year age group provided it is undertaken in a tightly controlled environment.

Introduction

The involvement of children in underwater activities started growing in the mid-1980s. Diving instructors and physicians were faced with the need to develop programmes for the training of young divers in optimal conditions that balanced children's satisfaction with maximizing their safety. Guidelines for the medical assessment of adult divers were well established. However, courses sponsored by national certifying agencies introduced new minimum age limits of 12 to 14 years. No suggested standards for evaluating prospective paediatric divers for diving course participation from this age were available at that time.

A review of the physiology and the most common problems associated with scuba diving in the paediatric age group proved to be based largely on medical opinion, as there were only limited data in the literature.[1–8] The growing popularity of recreational scuba diving resulted in a proportionately increasing number of paediatric subjects of all ages being referred to physicians for medical examination to determine their suitability for diving courses and active diving.

Therefore, we undertook a study to establish and assess a system of scuba diving initiation for children based on a children's diving club, Les Marmottes et Castors Palmés, Brussels, Belgium. This attempted to optimize communication between instructors, parents and a sports medicine specialist, and was focused on safety and the prevention of diving or other injuries.

Subjects and methods

All children interested in learning to scuba dive were entered into a prospective study of sport-diving medical evaluations over an eight-year period between 1985 and 1992. Written informed consent prior to study entry was obtained from the parent or guardian of each child. They underwent an annual sports medical evaluation including a complete physical examination with a special focus on ENT aspects. An audiogram, pulmonary function testing, including vital capacity and peak flow, plus resting and exercise electrocardiograms (ECG) were done. Children between six and eight years old had a bi-annual evaluation.

An electroencephalogram (EEG) was performed only as part of the initial medical examination. If an immature cerebral electrical pattern was found the EEG was repeated annually, or at least before open water diving, until a normal adult pattern was established. Children with a clinical diagnosis of asthma and/or abnormal pulmonary function testing underwent measurement of bronchial hyper-reactivity. All the medical evaluations, pulmonary function testing and resting and exercise ECGs were performed at a sports medical centre by one physician (GV). If additional

medical investigations were required, the child was referred to the appropriate specialist, e.g., a chest physician for extended pulmonary function evaluations including measurement of bronchial hyper-reactivity, or a cardiologist for additional cardiovascular investigations. Modified adult guidelines for children based on the available literature and other medical data were used to determine participation in the pool diving course and then open water scuba activities.

The children participated in swimming pool sessions lasting up to one hour per week from September till June over the eight-year period of the study. The objectives of the indoor pool sessions were:

- introduction of the child to scuba diving and the equipment to be used;
- progressive acquisition of diving skills before open water experiences;
- regular training during the year independent of weather conditions; and
- preparation of the young diver for specific underwater activities like photography and archeology.

A variety of open water dives were organised during the year once children had acquired sufficient basic skills and a knowledge of the underwater environment. They also needed to be able to enter the water from and re-board the boat. These dives were limited to a maximum depth of 5 m for certified divers aged eight to 12 years old and 10 m for certified divers aged 12 to 14 years.

Results

Two hundred and thirty-four children between the ages of six and 13 years entered the study over an eight-year period. The average follow-up was five years with a range between one and eight years. Twenty nine children (12.4%) were disqualified on medical grounds from participating in open water diving, 12 (5.1%) because they did not complete the initial medical assessment. Of the remaining 17 children, 12 (5.1%) had abnormal EEG. patterns, four (1.7%) children were asthmatic with abnormal bronchial reactivity and one child had sickle cell anaemia (Table 1).

All children below the age of eight were disqualified from open water diving, mainly because they did not complete the initial medical assessment or due to immature EEG. patterns.

The remaining 205 children were assessed as medically fit to undertake diving training. They completed up to a maximum of 303 scuba diving training sessions in the swimming pool (average per child per year = 37, range 25–44). A total of 2216 open water dives were completed by children in the programme during the eight years (average dives per diver per year = 11, range 0–18 dives). None of the children undertook open water diving until the age of ten. Twelve open water diving trips were conducted with 20 to 29 children on each trip, each child completing four to seven dives per excursion.

TABLE 1
OUTCOME OF SPORTS MEDICAL EVALUATIONS FOR CHILDREN

		N	(%)
Number of children enrolling		234	
Age:	less than 8 years	12	(5.1)
	8 – 11 years	181	(77.4)
	12 – 13 years	41	(17.5)
Disqualified		29	(12.4)
•Incomplete examination (EEG and/or ECG)		12	(5.1)
•Abnormal EEG (irritable signs)		12	(5.1)
•Asthma		4	(1.7)
•Sickle cell anaemia		1	(0.4)
Approved for scuba training		205	(87.6)

Fifty four incidents (26.3% of qualified children) and five accidents (2.4% of qualified children) were reported during the eight years of pool training sessions. No incidents or accidents occurred during the open water dives.

The incidents most commonly encountered were related to the ear: Eustachian tube dysfunction (12.2%), wax build-up in the external ear canal (5.4%), and otitis externa (3.9%). There was only one case of otitis media (0.5%) related to diving and one epistaxis (0.5%) (Table 2). All these incidents were minor.

Five accidents (2.4% of qualified divers) were reported, all with full recovery. Four tympanic membrane perforations occurred, two of these in the same child, and all during the first year of the programme. After the implementation of a special training focus on techniques of ear clearing, no further perforations occurred in the next seven years. One potentially life-threatening accident was a breath-hold hypoxic syncope in a twelve-year-old child, due to hyperventilation before this exercise (Table 3). These five accidents occurred during the swimming pool sessions in the age group of eight to 12 years.

TABLE 2
INCIDENTS OCCURRING IN 205 CHILDREN AGED 8 – 14 YEARS DURING SWIMMING POOL SCUBA TRAINING

	Number	(%)
Eustachian tube dysfunction	25	(12.2)
Wax build-up external ear canal	11	(5.4)
Otitis externa	8	(3.9)
Mycosis (body)	7	(3.4)
Otitis media	1	(0.5)
Dental pain (caries)	1	(0.5)
Epistaxis (diving)	1	(0.5)

TABLE 3
ACCIDENTS OCCURRING IN 205 CHILDREN AGED 8 - 14 YEARS OLD DURING SWIMMING POOL SCUBA TRAINING

	N	(%)
Tympanic membrane perforation	4	(2.0)
Syncope during apnoea	1	(0.5)

During the follow-up period, no subsequent developmental problems, with special focus on growth, pubertal development and hearing, were identified in these children.

Non-medical dropout from this study was caused by children leaving the scuba diving school. This percentage was quite low – average of 25% per year – compared with adults who have up to 45% dropout per year at some schools in Belgium. The reasons for leaving were varied. Common reasons were children of European Community agents on duty in Brussels returning to their home country at the end of their two -year contract (14%); children moving to another district (31%); children experiencing family problems (divorces, death of one parent, financial difficulties, etc) (35%); changes of sporting activity (10%); and other reasons (lack of interest, parental fears about scuba diving, bad results at school, etc.). Follow up of children from the first two categories suggested they commonly continued their scuba diving in their home country or new location. All drop outs were compensated for by new entries to the diving school due to the high demand for scuba diving training for children.

Discussion

Respiratory, cardiovascular, ENT, musculoskeletal and thermoregulatory characteristics of children impact on their ability to cope with the underwater environment. Children have their own specific needs in diving and should not be considered simply as scaled-down adults.

Before the age of seven to eight, there are risks of dyspnoea, hypoxia and pulmonary barotrauma due to the immaturity of the lungs. Pulmonary maturation progresses with growth, and the number of pulmonary alveoli increases till the age of about eight years. Elasticity of the lungs continues to develop till about 12 years of age. Airway resistance is higher and passive expiration longer. As much as 30 % of the alveolar units demonstrate low ventilation-perfusion ratios before the age of seven due to early small airways closure, with a theoretical risk of air trapping and pulmonary barotrauma.

These ventilation-perfusion changes and a possible increased incidence of patent foramen ovale may modify inert gas washout in young children. However, the risk of damage to long bone development at the level of the epiphyses is low since this cartilaginous growth plate is well vascularised with a good blood flow,[3,9] and probably has a shorter inert gas washout period compared with adult bone. The osteo-articular risk in paediatric scuba divers is mainly linked to carrying heavy weights (tanks, etc.) with possible lesions to the ossification centres.

Increased heat loss in children compared with adults necessitates careful attention to thermal protection to avoid hypothermia during diving. Good hydration and changing out of the diving suit in a warm environment immediately after diving minimises the likelihood of hypothermia.

Children's psychological maturity, their ability to comprehend instructions and procedures and their behavioural responses, including evidence of anxiety, require careful evaluation. One should also be aware that during open water dives a child needs good visual reference points, such as the pool wall, the descent/ascent line or the reef or sea floor.

Medical clearance to dive was given only after an evaluation based on a team approach, doctors, parents and instructors, which took into account all these different factors. In this Belgian children's diving club this was centred around the sports medicine specialist in charge of the diving. We continue to evaluate children on at least an annual basis, and have now set a minimum age of eight years for participation.

Ear problems were far and away the most common incidents or accidents in these children. Special attention to ensuring each individual child understands and practises ear clearing both at the medical evaluation and during swimming pool training is essential to reduce the risk of tympanic membrane perforation. Provided this is done properly few problems arise in practice.

Breath-hold hypoxic syncope, a potentially life-threatening accident, can be avoided if apnoea is limited to a maximum of 30 seconds after the age of eight years and hyperventilation is prohibited before the age of 10 years and strictly limited until the age of 14 years.

Modified diving equipment and well-fitting diving suits are essential. Attention is needed to weight and size, changes in configuration to facilitate donning, use and comfort in the water and security of fit.

Education and training must be focused on and adapted to the individual child. Classification of children for training sessions is based on individual capabilities and their stage of physical development. For open water dives the environment has to be selected carefully, and is ideally warm, in clear water with no current, and has a limited depth profile and easy access. Supervision of the diving must be planned carefully (Table 4).

TABLE 4
BASIC REQUIREMENTS AND RULES FOR TEACHING CHILDREN TO SCUBA DIVE

Specific educated and trained team:	(Sports) doctors, instructors, parents	
Specific sports medical evaluation:	One per year or more	
Minimum age:	Eight years old	
Modified equipment:	Weight, size, form, security, facilitate donning	
Modified education and training programme:	Focused on the individual child	
Selected environment:	Clear, warm water, no current, easy access	
Minimum water temperature:	12°C	
Limited depth:	8–14 years	initiation max. 3m
	8–12 years	certified max. 5m
	12–14 years	certified max. 10m
Maximum dive time:	10 min (12°C); 25 min (>12°C)	

Our experiences combined with other international data have been used to establish the Fédération Belge de Recherche et d'Activités Sous-marines/Belgische Federatie voor Onderwater Onderzoek en Sport (FEBRAS/BEFOS) and Confédération Mondiale des Activités Subaquatiques (CMAS) standards for children and diving.[10–13]

Conclusions

Periodic diving medical examinations based on modified guidelines for children and optimal communication between instructors, parents and the sports physician resulted in safe diving with a low incidence of problems in a children's diving club in Belgium over the eight-year period studied.

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References

1 Pouliquen H. L'Enfant et la plongée. *SPUMS J* 1982; 12(4): 3
2 Bylander A, Tjernstrom O, Ivarsson A. Pressure opening functions of the Eustachian tube in children and adults with normal ears. *Acta Otolaryngol* 1983; 95: 55-62
3 Teot L, Gilbert A, Amichot G, Berniere J, Pous JG, Carlioz H. Epiphyseal vascularisation during growth: the upper limb. *Annales de Chirurgie de la Main* 1984; 3: 237-244
4 Ibrahimoff O. Naissance et croissance: la plongée hyperbare en question. *Méd du Sport* 1984; 85: 192-201
5 Missirliu C. Préparation et initiation à la plongée chez l'enfant prépubère. *Méd du Sport* 1984; 85: 209-211
6 Carrier C. Regard psychodynamique sur l'enfant en situation de plongée en scaphandre autonome. *Colloque Plongée Enfants*. Paris: S.N.M.P. 1985; 1: 79-82
7 Carrier C, Duvallet A. L'enfant et la plongée: Mise en place d'une étude de la croissance. *Colloque Plongée Enfants*. Paris: S.N.M.P. 1985; 1: 77-78
8 Dembert M, Keith J. Evaluating the potential pediatric scuba diver. *Am J Dis Child* 1986; 140: 1135-1141
9 Wirth T, Syed Ali MM, Rauer C, Suss D, Griss P, Syed Ali S. The blood supply of the growth plate and the epiphysis: a comparative scanning electron microscopy and histological experimental study in growing sheep. *Calcified Tissue International* 2002; 70: 312-319
10 A.R.P.E. (Association de Réflexion pour la Plongée des Enfants - Argenteuil - France). Cinquièmes Cahiers de l'A.R.P.E. *Pratique de la plongée par les enfants sur le territoire français*: Compte rendu d'étude, 1993
11 Collard F, Collard F. *Manuel de l'Instructeur de Plongée Enfant n°1*, Expériences de Physique en Piscine. Ed. Guilim, 2000
12 Collard F. *Manuel de l'Instructeur de Plongée Enfant n°2*, Plongée Enfant Entrainement. Ed. Guilim, 2000
13 Collard F, Collard F. *Manuel de l'Instructeur de Plongée Enfant n°3*, Physiologie, Structures, Organisation. Ed. Guilim, 2001

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