



A popular summary of a private literature collection about the medical aspects of competitive diving

A safe but demanding sport

By Wes Zimmermann, M.D.*

To the spectator diving is a beautiful and potentially dangerous sport. Spectacular accidents can happen and are televised in news bulletins the world over. To diving coaches and participants accidents are not the main concern. They struggle with the daily frustration of overuse injuries, that keep divers from optimal training and competition form.

What does the medical literature say on diving accidents and injuries? This review tells you where to find articles on the medical aspects of diving, what is written in them and what is missing.

A private literature collection

Starting in 1985, the author has compiled a bibliography on competitive diving with 3300 references to books and articles. Many of the books and articles have been collected via university libraries, colleagues and the internet. The complete list of titles is directly accessible for everybody through www.springschool.nl.

For this review 251 articles marked as "medical" in the bibliography were grouped according to topic. Table 1 shows the number of articles per topic, whether they are available in the private collection (yes / no) and the years of publication. In the following three paragraphs the articles in the collection (150) on most topics are briefly summarized.

Expert opinion, questionnaires and safety research

Experts agree, diving is a safe sport, when calculating the number of recorded deaths (two divers in the 1980's, both on dive 307c, 10 meter) and permanently paralyzed (one diver, 1965, Japan).

Wrist and thumb taping allows divers to continue training (in the photo, Ruolin Chen from China) ▲

Table 1: 251 articles on the medical aspects of competitive diving, regrouped in 21 topics

Topic	Number	Yes	No	Years
Expert opinion, questionnaires, safety				
1 expert opinion (injuries and prevention)	23	16	7	1945-2001
2 questionnaires / epidemiology	16	8	8	1940-2002
3 safety research	31	12	19	1961-2001
Areas of concern				
4 head / neck injuries	15	10	5	1960-2004
5 back injuries	13	10	3	1969-2006
6 case reports	13	12	1	1972-2006
7 nutrition / eating disorders	10	5	5	1985-2006
8 shoulder injuries	8	7	1	1982-1999
9 wrist / hand injuries	8	6	2	1981-2006
10 eyes / lenses	6	4	2	1979-1991
11 ear / nose / throat	6	2	4	1949-1998
12 neurology	5	3	2	1981-2000
13 skin	3	3	0	1987-1992
Training the body of the diver				
14 orientation / vestibular organ	22	9	13	1971-2001
15 human movement sciences	17	9	8	1961-2000
16 bodybuild / medical measurements	17	12	5	1966-1998
17 treatment / therapy	12	9	3	1987-1999
18 talenttesting / measurements by coaches	15	6	9	1977-2006
19 physiology	7	3	4	1975-1990
20 age group / masters	2	2	0	1991-1999
21 heart	2	2	0	1988-1994
	251	150	101	

Experts also agree that divers can have many types of accidents and injuries. This is due to the diverse nature of the sport, diving has both a high speed impact and chronic repetitive character and also to the different locations a diver receives

training: in- and outdoor pools, dry-land areas with boards and mats, on a trampoline, in a weight room. To put it simply: any injury imaginable can and probably has occurred in springboard and platform diving.

To discover the number and nature of the injuries of divers several questionnaire studies have been undertaken (2002 Canada, 1993 USA, 1985 Japan, 1982 Switzerland, 1981 USA) and one prospective study (1993, Netherlands). All studies show the same trend: most divers had injuries at some point in their career, many in the last 12 months before the survey and the majority of divers reports competing with injuries, at the time of the questionnaire. All authors come to the same conclusion: *elite divers deserve and should actively seek more medical attention.*

Safety research has concentrated on the prevention of catastrophic (head and neck) injuries. From these studies a simple advice can be extracted: only dive in a diving pool that is build according to FINA recommended minimum dimensions and find a qualified coach.

Doctors and diving: areas of concern

A 2006 MRI study of divers of the Swedish national team confirms what experts had already warned for 35 years ago. Divers very often have back pain. They have more abnormalities of the spine on x-ray and MRI than non-divers and in a five year follow up the number of MRI abnormalities of the spine increased. This is the strongest evidence so far that competitive diving has an adverse effect on the back, especially in youngsters, who are still growing. It is up to the coaches, the divers and their parents to determine how far they want to push the limits. In a 1982 Swiss survey 8 of 11 retired divers, in the age category 20-30 years old, complained of back problems which they attributed to their diving careers.

In 1991, a high incidence of shoulder injuries among American elite divers was reported, 16 of 20 divers were afflicted. It was found that the symptomatic (painful) shoulder had a lack of muscular strength in the direction of external rotation. Strengthening exercises in this direction seemed a logical preventative advice. Unfortunately there are no follow up reports since, it is not known if the prevalence of shoulder injuries has dropped.

In 1993, 18 of 21 platform divers at the French national championships indicated that they had occasional or frequent wrist pain. The injured wrist was always the top hand in the flat-hand-grab water entry technique. Worldwide most divers have switched from a two fist (thumb in fist) entry technique around 1980. Shortly after came the first reports on wrist injuries in divers, linked to the new entry technique. Taping the wrists, to prevent maximal dorsal flexion when hitting the water, seems a particularly effective treatment to keep divers in training.

Extensive neurological testing of 31 divers, with a mean age of 13,3 years, in 1981-1982, in the former republic of Czechoslovakia, produced the following findings: 72% of the divers had an increase of the threshold of the acoustic reflex, 51% of the divers had abnormal results in stan-

darised medical tests of the vestibular system. The authors concluded that these symptoms represented evidence for repetitive brain micro-injuries. It is not known whether the symptoms are reversible and if divers suffer consequences later in life. Other authors have suggested that it would be wise to develop protective headgear for divers, considering the forces that act on the divers head when hitting the water from 10 meter platform (repetitively), or when hitting the platform with the head (accidentally). In a more recent study, in the year 2000, divers were given neuro-psychological tests before and after diving from 1- and 3-meter springboards. No difference between pre- and post diving scores could be detected.

Chinese authors show great concern with the eyes of divers on the national team. From six years observation on 54 divers, 50 were found to have different degrees of retinal and vitreous humour diseases (vitreous humour = the gel filling of the eyeball). It is believed that hitting the water surface upon entry and the effect of water pressure after entry are directly related. The authors assume that their findings have "always been under concern", however none of the articles found for this review mention eye injuries in divers more than briefly. More information on this topic and follow up research seems required.

The full-blown female athlete triad; disordered eating + menstrual dysfunction + low bone mineral density is a rare condition. However a significant number of female divers suffer from individual disorders of the triad. It is therefore recommended to include a weight, dieting and menstrual questionnaire in pre-participation and follow up medical screenings. On the related, but different topic, of vitamin and mineral supplementation the following was found: female swimmers and divers do not develop a vitamin or iron deficiency during a 4 months intensive competitive season, when given a single daily dose of an over-the-counter multi-vitamin product and nutritional advice by a dietician at the start of the season.

Training the body of the diver

At the 1964 Tokyo Olympics for the first time the bodies of divers were subject to study. Only age, height and weight were recorded. In the following years, at several occasions, this was repeated and the number of body dimensions measured, with the diver in resting position, steadily increased. The results can be summarized as follows: divers are smaller than the average population, they have broader shoulders, narrower hips and a lower body fat percentage. Divers are similar in body build to gymnasts, male divers even more so than female divers. Elite junior divers have the same body types as elite senior divers. Based on one study, following 20 divers for one year, it has been concluded that, compared to non-athletes, the growth rate of young divers is normal and the age at first menstruation is later, but not as late as in gymnasts.

The next step in understanding the body of the diver was to investigate it during motion. It is not yet possible to measure exactly which muscles are active during a dive, myographical electrodes are not yet waterproof. Describing which muscles are used by the diver in the air remains a theoretical endeavour. With the help of high speed cameras and modern software it is possible to see in slow motion the angles of the body parts during the dive. From this it can be estimated how much flexibility is needed in the joints of divers and at which angles the muscles must deliver force. On the biomechanical aspects of diving many more articles are written than on the medical aspects. Medicine and biomechanics do have an interesting overlap.

Testing the muscles of divers in the doctor's office shows patterns of training deficits. In divers the following muscles are at risk for shortening: m. rectus femoris (front of upper leg), m. tensor fasciae latae (side of upper leg) and m. trapezius pars descendens (side of neck). Muscles at risk for weakness are: the flexor muscles in the front of the neck, m. serratus anterior (from shoulder blade to ribs) and m. rectus abdominis (the abdominal muscles). From this it can be concluded that only a doctor who knows the sport of diving can design a useful medical screening protocol for divers.

Around 1980 US diving published its first papers on physical tests to identify talented divers. The process of identifying talents among divers who are already competing is called "talent selection", the process of finding talents among non-diving schoolchildren is called "talent identification". Only one study presents the results of 250 divers aged 8-18 on five physical performances items (1991, USA) and one study presents the results of testing 236 schoolchildren, ages 8-11, on ten physical performance items (2006, The Netherlands). So far the predictive value of the talent tests (do the selected divers become champions?) has not been evaluated in the literature.

Orientation during flight is achieved by the combined input to the brain from the visual system, the vestibular organ and the somatosensory-system. The somatosensory-system is composed of the tension receptors in muscles, tendons and joints. Divers refer to the somatosensory-system as "the feeling of one's body position in the air". Disorientation can happen when a person is rotated in the air. The vestibular system informs the brain that the body is changing direction in the air, the eyes make involuntary movements and briefly lose focus. Scientists in the former republic of East Germany have clearly proven that trained divers are better than schoolchildren of the same age in identifying shapes and figures while being spun around in a laboratory somersaulting and twisting machine and less disoriented immediately after. With an intensive training program in a somersault machine, with rapid rotations, the disturbance of the vestibular system can be reduced and therefore the ability to focus with the eyes dur-

ing rotation can be improved. After eight weeks of rest the training effects are lost. It is therefore necessary to keep training rotations on a daily basis, to prevent loss of orientation ability.

What is missing in the literature?

251 articles on the medical aspects of diving is not much. Typing "gymnastics" in www.pubmed.gov provides more than 2100 articles in medical publications (August 2007), with 30 articles published in 2007 and 60 articles in 2006. Table 2 shows that the articles used in this review are mostly written in the 1980's and 1990's. Diving seems to be losing the interest of medical researchers.

The quality of the diving research is also not up to date. Studies on injuries and accidents based on expert opinion are nowadays considered suboptimal. Modern standards in sports medicine demand evidence, based on continuous registration of injuries and proof (measurement) of the effects of preventative recommendations.

Table 2: year of publication of the articles on the medical aspects of diving

2000-present	19
1990-1999	98
1980-1989	84
1970-1979	35
1960-1969	10
1950-1959	2
1940-1949	3
Total	251

This review of the literature shows diving to be a safe sport with regard to major, catastrophic accidents. The number of reported overuse injuries of the neck, back, shoulders and wrists and possible irreversible damage to the eyes, ears and vestibular organ of divers is very disconcerting. Divers are advised to actively seek medical care for their injuries. Diving federations are encouraged to initiate more research and publications on the medical aspects of diving.

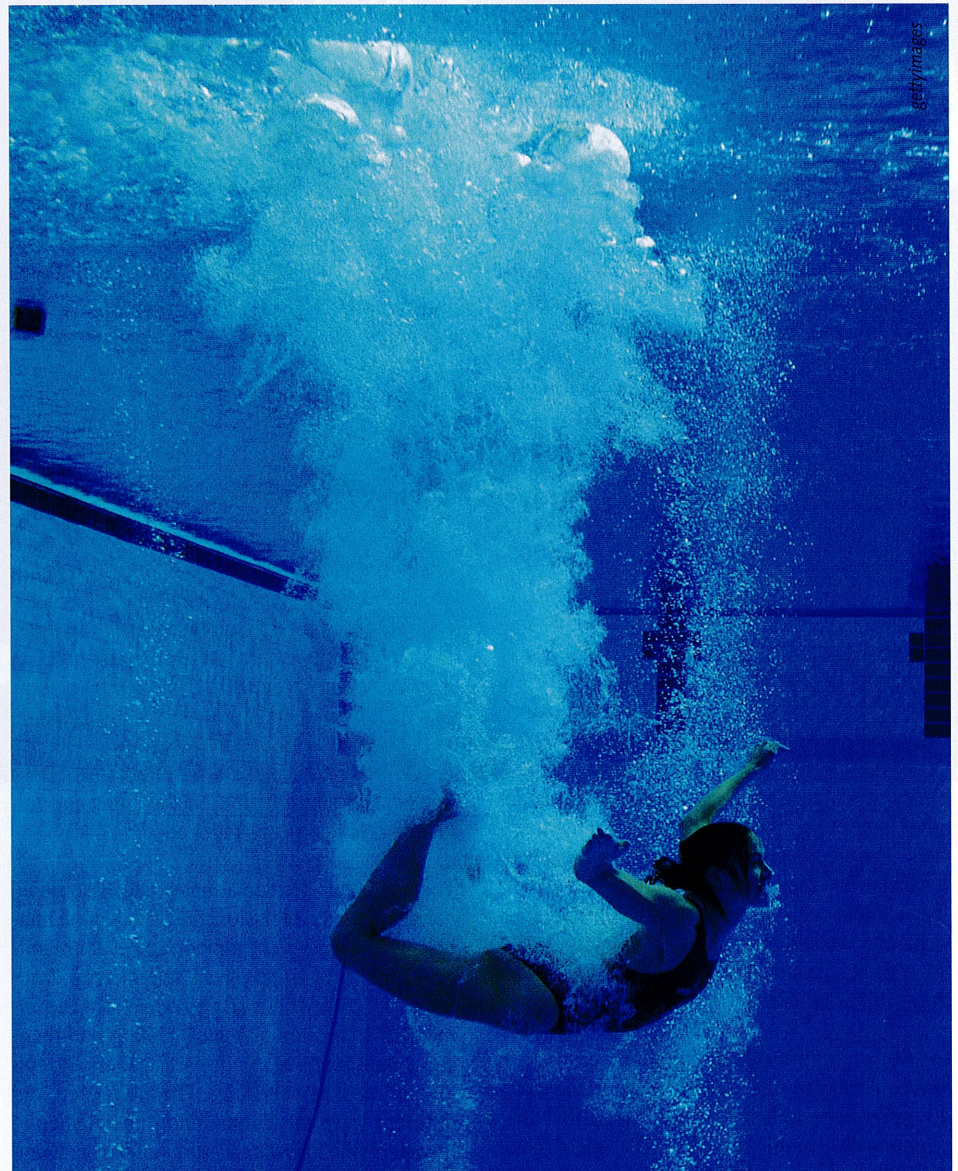
Key points:

- Diving literature is available on www.springschool.nl
- Divers have few catastrophic accidents
- Divers have many overuse injuries
- Divers should actively seek more medical care
- Modern research on the medical aspects of diving is needed.

Recommended reading:

1. Diving, by Benjamin D. Rubin and Steven Anderson, in: Epidemiology of sports injuries, Dennis J. Caine, published 1996, ISBN 0-87322-466-3, pages 176-185.
2. U.S. Diving safety training manual, second edition, Janet L. Gabriel, editor. US Diving, Indianapolis, Indiana, 1999.

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cialised in the rehabilitation of sport and work injuries. He works for the Royal Dutch Army in the department of occupational medicine. He is also a former international diver (1978-1991) and current part-time age group diving coach, responsible for the regional diving centre Diving Amersfoort, in The Netherlands. His best diver placed number 9 in the 2006 world junior championships on platform, in the category girls 16-18.

Does under water pressure affect diver's eyes and ears? ▲

ASK THE DOC

I am the parent of a child who is interested in becoming a diver. Is Diving a safe sport?

As outlined in the article by Dr. Zimmerman, diving in the proper facility under the guidance of a trained coach is quite safe. Catastrophic injuries are very rare. Overuse injuries do occur in the elite diver and more research and education on the prevention of these injuries is required.

As a team manager, what should I look for at diving competitions to ensure medical safety for my athletes?

Thank you for your important question on event safety. It is essential to ensure that there are lifeguards on site during training and competition. Also, the lifeguards should be trained in emergency removal of the injured swimmer – including the diver with a potential cervical spine injury. There should be a spinal board on deck and an emergency transport system (ambulance) on site. Ideally, there should be present someone trained in advanced first aid – either a physician or a paramedic/trainer.

2008 FINA SPORTS MEDICINE CONGRESS NEWS

The website for the 2008 FINA World Sports Medicine Congress in Manchester (GBR) is now up and running including on-line abstract submission. Take a look on www.Manchester2008.org/-sportsmedicinecongress