Water Safety and Diving Safety – Preventing injury through safer diving -Jenny Blitvich

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Introduction

Each year, approximately 25 Australians sustain a catastrophic spinal cord injury (SCI) from a shallow water diving incident (1). The most common injury is of C5/6, resulting in tetraplegia or tetraparesis (2). Most of the injured are males in the 15-34 year age range. Typically, their diving skills are self taught (3) and they are unaware of the dangers associated with diving into shallow water and the skills required to perform 'low risk' dive entries. In 50-80% of cases, alcohol consumption is involved (eg.4).

The financial burden of such injury is great, impacting upon the injured person and their family as well as the Australian community as a whole. Walsh (5) estimated the financial cost of each spinal cord injury to be $1.2 million, as measured in 1987 dollars. Life expectancy is decreased by 15 – 25 years following spinal cord injury (6). The emotional and social impact can only be imagined.

The importance of reducing the rate of diving SCI has been recognised by both Commonwealth and State Governments in Australia (7, 8). However, worldwide, diving SCI prevention programs have focussed only on increased awareness and have demonstrated little if any impact on the incidence of injury (4, 9, 10). Increased awareness alone is not sufficient. A comprehensive approach is required, addressing skills and policy, along with public awareness.

Most research in diving considers competitive performance (11-13), investigating the effect of different dive entries on performance, rather than on safety. Diving SCIs are usually sustained by recreational swimmers, who tend to have a lower skill level than their competitively trained counterparts. This paper discusses a series of studies, conducted at the University of Ballarat in conjunction with The University of Western Australia. The first study examined characteristics which distinguished 'low risk' and 'high risk' dives among recreational swimmers. The second study involved teaching safer diving skills to a group previously identified to be of low diving skill level, while the third study tracked these participants over time, to establish whether their newly acquired skills were retained over the long term, without further intervention.

Characteristics of 'low risk' and 'high risk' dives among recreational swimmers (14)

Ninety-five first year university students (average age 19.9 years) performed three or four dives which were video-recorded for later analysis. The types of dives investigated were: dive entries from deck level to tread water (Treadwater); deck level to swim 25 m (Deck); starting block height to swim 25 m (Block); and for those comfortable to do so, a running dive entry to swim 25 m (Running). Maximum depth reached was used as an indicator of risk, and velocity at maximum depth, distance at maximum depth, angle of entry and flight distance were measured for each dive. Descriptive analysis was used to examine hand and arm position during the underwater pathway of the dives. Participants also completed a questionnaire designed to elicit information about their swimming and diving background. Unlike previous diving studies, participants were recreational rather than competitive swimmers. To mimic the circumstances where injury occurs, they were not aware that the dive was the focal point of the study, assuming that the researchers were investigating their swimming and treadwater ability.

Statistical analysis determined which dive parameters made the greatest contribution to dive depth. Stepwise multiple regression was applied to predict depth for each dive condition and comparisons among selected variables were made using beta weights of the resulting multiple regression equations.

The Treadwater dive condition was found to have the greatest depth, and hence the greatest risk. This is the type of dive likely to be performed by a recreational swimmer who is entering the water to 'play' rather than to swim laps. Entering the water for 'play' is a typical circumstance when SCI is sustained. Angle of entry was found to be the most influential variable, followed by velocity at maximum depth, distance at maximum depth and swim rank. In all conditions involving swimming after the dive (ie Deck, Block and Running), distance at maximum depth was shown to have the greatest influence on the depth of a dive. Flight distance and angle of entry were the next most influential variables. Other findings of this study were:

- skill levels of participants varied widely
- depths reached also varied widely (0.14 m to 1.78 m, as measured at the ear-hole)
- velocity at maximum depth was sufficient in all 316 dives to dislocate cervical vertebrae
- velocity at maximum depth was sufficient to crush cervical vertebrae in 310 dives

Several factors were found to contribute to safer dives. Safer dives were shallower, with hands locked together and arms extended beyond the head offering protection against impact. Locking hands together was important to prevent the arms being forced apart upon impact with the water. The level of risk was increased for some participants who allowed their hands to break apart and

pull backward to perform a breaststroke arm action at, or before reaching maximum depth. In pulling both arms backward, the head and neck were left exposed and unprotected.

Individuals who performed safer dives implemented steering techniques. Hyperextension of the hands at the wrists, raising the upper trunk and arching the back, and slight hyperextension of the neck along with raising the arms were used to aid steering-up towards the surface. Flight distance, distance to maximum depth and angle of entry also affected dive depth. Participants with longer flight distances, shorter distances to maximum depth and shallower entry angles performed shallower, safer dives.

The findings of this study indicate that every dive entry has the potential to cause spinal cord injury should impact with a solid surface occur. It is recommended that divers strive to surface in as short a distance as possible by maximising flight distance and aiming for a low entry angle. Implementation of steering-up techniques will assist in minimising dive depth.

Teaching Safer Diving Skills (15)

Thirty-four recreational swimmers identified from study one to have low diving skills took part in an intervention program to improve diving skill. Participants completed seven 10-minute session which emphasised locking hands together ("Lock Hands"); extending the arms beyond the head to lock the head in position ("Lock head"), and developing steering and gliding skills ("Steer-up").

Diving skills sessions were conducted at the end of the regular swimming classes which were part of the participants' university course. Initial sessions (sessions 1-3) were conducted in the shallow end of the University of Ballarat Aquatics Laboratory (1.2 m deep) and did not involve head first entries. Gliding and steering skills, with "hands locked" and "head locked" were performed. The following progressions were conducted:

1. completely submerge, then push off the wall and glide forward in a streamlined position
2. completely submerge, push off the wall in a streamlined glide and steer the body to the surface
3. completely submerge, push off the wall in a streamlined glide, steering the body through hoops placed at various levels and surfacing through a hoop
4. push off the bottom of the pool and steer over and under a series of foam 'noodles' to surface through a hoop

Once steering and gliding skills had been acquired, and participants were consistently maintaining the "lock hands" and "lock heads" positions, it was safe to move onto head first entries at the deep end of the pool (2.0 m). As students had already spent approximately 30 minutes practising steering and gliding activities, they progressed rapidly through the remaining sequential steps. The sequence moved through sitting, crouching and standing dives. The sitting dive was considered of great importance, as this was used to ensure participants acquired skills in achieving horizontal rather than vertical velocity. Students sat on the edge of the pool, with their feet positioned flat

against the side wall of the pool. In the "lock hands, lock head" position, they extended their body forward, and pushed firmly with their feet against the pool wall. They were asked to imagine that their body was stretched out horizontally, and that their feet gave a final push to propel them through the water. Upon entry, they used steering-up skills to keep the dive shallow.

Following mastery of the sitting dive, participants moved quickly through the crouching and standing dive and then onto dives from block level. The need to maintain the "lock hands, lock head" position was continually emphasised, along with implementing 'steering-up" skills. Achieving a long flight, and therefore a shallow angle of entry was also highlighted.

At the conclusion of the intervention program, another video-recording session was conducted, and participants repeated the same dive entries as at the initial filming session. The same parameters were measured, and repeated measures ANOVAs were conducted to determine whether dive depth and other parameters had changed. Maximum depth was significantly decreased, and the action of performing a breaststroke-like arm action was completely eliminated. Both these factors contributed to safer dives post-intervention. Locking the hands together improved markedly, with hands allowed to separate in 71% of dives pre-intervention, but only in 3% of dives post-intervention. The treadwater dive, which was found to be the deepest and hence most dangerous pre-intervention, demonstrated the greatest decrease in depth following intervention. Velocity in all dives was sufficient to damage vertebrae, reinforcing the fact that every dive has the potential to result in catastrophic injury.

Retention of Safer Diving Skills (16, 17)

To determine whether the skills achieved in the diving skills intervention program were maintained without further practice, participants were invited to return for another data collection eight and 20 months after the conclusion of the intervention. Twenty-two students attended the Post-8 data collection, while 21 attended the Post-20 session. These time periods were matched to the time between the end of one summer and the beginning of the next (eight months) and then the beginning of the following summer. The same video-recording procedures were followed, and participants also completed a survey designed to determine whether any formal swimming or diving instruction/practice had occurred since the intervention program. Repeated measures ANOVAs were again conducted to determine statistical significance.

This study showed that skills were maintained over the extended retention period. Extremely little diving had occurred in the intervening period, reinforcing skill maintenance in the absence of practice. This is an important finding, as every dive, even the first after a long break, must be safe to avoid the possibility of injury. None of the participants performed the dangerous breaststroke-

like arm action at Post-8 or Post-20. The number of students who did not lock their hands together on entry increased slightly but was below the level observed among these participants pre-intervention.

For the Treadwater dive condition (the most dangerous pre-intervention) the significantly shallower dive depth achieved after the intervention program was retained over both the long (Post-8) and very long term (Post-20).This indicates that for adults a short period of instruction resulted in a relatively permanent change in this important measure.

Conclusions

The findings demonstrate that if learn-to-swim programs formally incorporate a progressive practice sequence to teach diving skills, then there will be a decreased risk of swimmers sustaining a diving spinal cord injury. Adult learners who entered the intervention program with poor diving skills were able to maintain improvements in diving safety over a non-practice period of 600 days. If all recreational swimmers acquired the knowledge of the dangers inherent in diving, along with the skills necessary to perform low risk dive entries and implemented these skills during every head first entry, then the risk of sustaining a shallow water diving spinal cord injury could be minimised. Spending approximately 70 minutes on a diving skills program is a small time investment in a prevention strategy to protect against the possibility of a lifetime of tetraplegia following a diving accident.

For full details of these studies, see 14-17. For more details of the diving sequence, see 18.

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