ACTIVE & SAFE

Evidence Summary: Diving and High-Diving

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BC INJURY research and prevention unit

The British Columbia Injury Research and Prevention Unit (BCIRPU) was established by the Ministry of Health and the Minister's Injury Prevention Advisory Committee in August 1997. BCIRPU is housed within the Evidence to Innovation research theme at BC Children's Hospital (BCCH) and supported by the Provincial Health Services Authority (PHSA) and the University of British Columbia (UBC). BCIRPU's vision is *to be a leader in the production and transfer of injury prevention knowledge and the integration of evidence-based injury prevention practices into the daily lives of those at risk, those who care for them, and those with a mandate for public health and safety in British Columbia.*

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Evidence synthesis tool

SPORT:	Diving and High-Diving (not scuba)	**Target Group:**	Competitive (high schools and club-level to elite professionals) and recreational divers
Injury Mechanisms:	All Injury: Musculoskeletal or concussion injury sustained during diving training, competition or recreation		

Incidence/Prevalence	Risk/Protective Factors	Interventions	Implementation/ Evaluation	Resources
Competitive Diving The injury rate during professional games (competition and practice) is reported as 8.1% (female 5.9%, male 7.4%; 2012 Olympics)[1] and ranges from 114 to 134 injuries per 1000 athletes in diving and is 48 injuries per 1000 athletes in the high dive event (FINA World Championships 2009 and 2013).[2,3] In elite varsity NCAA teams, the diving injury rate in males is 1.94 (1.18 to 2.69) and in females is 2.49 (1.69 to 3.29). Shoulder injuries are common in males (32%); trunk injuries are most common in females (37.8%). Most injuries are classified as overuse (males 24%; females 21.6%).[4] Lower back pain is the most commonly reported injury in elite competitive divers with prevalence rates of 38.4-49% reported. [5,6] **Recreational Diving** In a systematic review of all sport participants, the proportion of spinal cord injury (SCI) in diving related to all-sport SCI was 35.3% (range 7.7-	**Competitive Diving** In elite junior male divers, *Shoulder flexibility* (O= 0.919; 95% CI 0.851 to 0.992) and *age* (OR=0.441; 95% CI 0.239 to 0.814) are recognized as risk factors related to lower back pain. Only *age* (OR=0.536; 95% CI 0.335 to 0.856) was a factor in female-elite junior divers.[5] **Recreational Diving** In all divers, risk factors for cervical spinal cord injury were assessed in two systematic reviews (2005 and 2008). Risk factors included consumption of alcohol (3.4% of all SCIs in Japan were sport-related under the influence of alcohol, while 30% of sport-related SCIs were under the influence of alcohol in the US)[7], presence of a pool party, water depth <1.2m, absence of a lifeguard on duty, non-competitive standard, reduced risk perception, poor lighting, hidden objects, lack of depth markings or warnings, lack of adequate	**Recreational Diving** Few prevention programs for diving-related injury or spinal cord injury have evaluated or published their outcome effectiveness. A systematic review[10] in 2008 descriptively evaluated interventions for the prevention of spinal cord injury in diving. The American Red Cross Swimming and Diving guidelines in 1992 required a minimum depth of water below the tip of the diving board in a standard public pool of 9 ft. No incidences have been reported of SCI in Olympic sized public pools that meet these criteria. Most diving related SCI (DSCI) occur in residential pools where the maximum depth is less than 9 ft. A number of education programs (see resources) on diving safety have been implemented in North America but not evaluated for effectiveness in reducing DSCI.	**Recreational Diving** In an assessment and evaluation of primary prevention in spinal cord injury,[14] it was found that a school-distributed educational video, *Sudden Impact (Think First),* was only viewed by an average of 16% of students in each school.[15] Little change in attitude and no consistent change in knowledge or behaviours were seen as a result of Think First in high school students. • Underuse of materials is an **implementation barrier** for many prevention programs that do not own the distribution channels for their work. • **Implementation facilitator** - In general, prevention programs (from non diving-related sources) with multimodal (including social media) components that include long-term follow-up and "booster" interventions	**Recommendations for interventions** based on evidence-based risk factors for DSCI have been published by Barss *et al* 2008 (personal, environmental and equipment interventions).[17] ThinkFirst – US National Injury Prevention Foundation – education for kids, youth and teens. http://www.thinkfirst.org/ Dive Smart (Parachute Canada) injury prevention programs http://www.parachutecanada.org/injury-topics/item/diving-and-injury-prevention-dive-smart-and-sudden-impact Sudden Impact leader's guide http://www.parachutecanada.org/downloads/injurytopics/Think_First__Sudden_Impact_LG_Eng_v3.2_2007_07_27.pdf

64.9%). This was the highest reported of all sports. The most common groups to experience high cervical SCI are adolescent and young adult experienced male divers. Almost all SCI related to diving (87%) occur in private or residential swimming pools. Non-competitive standard diving accounts for 70% of SCI cases. [7,8] In a representative sample of US Emergency Department records, there was an average yearly rate of 8.4 diving-related injuries seen per 100,000 US residents under age 20 years. [9]	design/legislation.[8,10] Protective factors for spinal cord injury include diving with maximized flight distance and a low entry angle with steering technique appear to be safest. Head and neck injury is reduced with hands held together, thumbs locked and arms extended beyond the head.[10]	One educational video to schoolchildren in Slovenia noted a decrease from seven DSCI per year to two DSCI per year after 3 years of education. A 60-min audio-visual (*ThinkFirst*) lecture on brain and <u>spinal cord injury</u> prevention significantly changed students' opinions about checking the depth of swimming pool 5 months later. This was the only attitude that changed after the educational intervention.[11] In public diving facilities, *more restrictive regulation of dive forms* was not associated with a decrease in <u>injuries</u> in the previous 12 months (p = 0.93). Risk was perceived to be lower for those with experience, and these people favoured less regulation.[12] An intervention (7 10-minute sessions) to improve diving skill in inexperienced divers was successful in significantly reducing diving depth (with lesser entry angles, improved hand/arm placement, greater flight distance and steering-up manoeuvre) in different dive types 20 months later. [13]	appear to be more effective than one-dimensional, one-time programs.[14] In structured interviews with 120 children (age 7-10y) that evaluated *"no diving" warning signs for shallow water,* children understood that breaking your neck results in limitations in mobility and can occur from diving, but they did not anticipate that such an injury is likely to occur.[16] • **Implementation Barrier** Younger children were less likely to interpret text information. Having diving experience biased children toward assuming less likelihood of injury. • **Implementation Facilitator** "Danger" should be the signal word of choice for warning signs targeting children. Explicitly saying on No Diving signs that one can "break your neck" may maximize effectiveness of the warning. In addition, providing active supervision by adults has been shown to reduce children's risk behaviours.[16]	

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Review of Sport Injury Burden, Risk Factors and Prevention

Diving and High Diving

Incidence and Prevalence

Diving is a sport that involves jumping or falling into a body of water from a platform or springboard at a measured height, usually involving some form of acrobatics before water entry. Performed competitively, it is an internationally recognized sport that is part of the Olympic Games. Thus, international sporting bodies have collected much of the injury prevalence data. The injury incidence proportion for competitive diving during professional games (competition and practice) is reported as 8.1% (female 5.9%, male 7.4%; 2012 Olympics) (Engebretsen et al., 2013). The incidence ranges from 114 to 134 injuries per 1000 athletes in diving and is 48 injuries per 1000 athletes in the high dive event (FINA World Championships 2009 and 2013) (Mountjoy et al., 2010, 2015).

At an elite level (American varsity National Collegiate Athletic Association - NCAA), diving injury incidence in males is reported at 1.94 per 1000 athletic exposures (AE) [95% Confidence Interval (CI) 1.18 to 2.69] and in females at 2.49 per 1000 AE (95% CI 1.69 to 3.29) (Kerr et al., 2015). Overall, injury rates do not differ between male and female divers [Incidence Rate Ratio (IRR)= 0.91; 95% CI 0.47 to 1.29] but are slightly higher in competition vs. practice. In males, the most common body site injured is the shoulder, comprising 32% of all diving injuries, followed by injuries to the trunk (20% of all injuries). The trunk; however, is the most commonly injured site in females (37.8%), followed by the hand/wrist (16.2%) and the head/face (13.5%) (Kerr et al., 2015). This finding is also reported in elite competitive divers with incidence proportions of lower back pain estimated between 38.4 and 49% (Badman & Rechtine, 2004; Narita et al., 2014). With respect to injury type, most diving injuries are classified as overuse injuries (males 24.0%; females 21.6%) and non-contact injuries (males 28.0%; females 27.0%). Contact with water also accounted for large proportions of injuries in men’s and women’s diving (32.0% and 16.2%, respectively) (Kerr et al., 2015).

In addition to competitive diving, non-competitive or unstructured diving is a recreational activity and can take place in many settings. Inadequate knowledge of water depth or surroundings can pose significant injury risk. Incidence/prevalence data for injury in recreational diving is often limited to occurrence of fatal spinal cord injury (SCI). Occurrence of non-fatal injury in private swimming pools, oceans, rivers and lakes are rarely reported. In a systematic review of all sport participants worldwide, the proportion of SCI in diving related to all-sport SCI was 35.3% (range 7.7-64.9%) (Chan, Eng, Tator, & Krassioukov, 2016). This was the highest reported of all sports. The most common groups to experience high cervical SCI are adolescent and young adult experienced male divers (Toth, McNeil, & Feasby, 2005). In a representative sample of US Emergency Department records, there was an average annual rate of 8.4 diving-related injuries seen per 100,000 US residents under age 20 years (Day, Stolz, Mehan, Smith, & McKenzie, 2008). Non-competitive standard diving accounts for 70% of diving-related SCI cases, while almost all SCI related to diving occur in private or residential swimming pools (87%) (Toth et al., 2005).

Risk and Protective Factors

Competitive Diving

The analysis of risk and protective factors for competitive diving is limited to one study investigating lower back pain in elite junior divers ages 12-17 years. The univariate results of this study suggest that there may be an increased risk of lower back pain with increasing age in junior male and female divers and with decreased shoulder flexibility in junior male divers (Narita et al., 2014). These results show that limited shoulder rotation width in males could lead to lumbar hyperextension when adjusting for the angle of water entry, increasing the risk of lower back pain.

Recreational Diving

In recreational divers, risk factors for cervical SCI were assessed in two systematic reviews (Chan et al., 2016; Toth et al., 2005) and one literature review (Cusimano et al, 2008). Risk factors included consumption of alcohol (3.4% of all SCIs in Japan were sport-related under the influence of alcohol, while 30% of sport-related SCIs were under the influence of alcohol in the US) (Chan et al., 2016), presence of a pool party, water depth <1.2m, absence of a lifeguard on duty, non-competitive standard, reduced risk perception, poor lighting, hidden objects, lack of depth markings or warnings and a lack of adequate design/legislation (Cusimano, Mascarenhas, & Manoranjan, 2008; Toth et al., 2005). Protective factors for spinal cord injury are related to diving technique and include diving with maximised flight distance and a low entry angle with a steering technique. Head and neck injury is reduced when the hands are held together, thumbs locked and arms extended beyond the head (Cusimano et al., 2008). In recreational diving, the magnitude of effect of reported risk and protective factors is unknown.

Opportunities for Prevention: Effective Interventions, Cost-Effectiveness, Implementation and Evaluation

Few prevention programs for diving-related injury or SCI have evaluated or published their outcome effectiveness in recreational diving, with no evidence-based programmes available for competitive diving. A literature review (Cusimano et al., 2008) in 2008 descriptively evaluated interventions for the prevention of spinal cord injury in diving with a number of highlighted programmes.

With regards to engineering and design of pools, the American Red Cross Swimming and Diving guidelines in 1992 required a minimum depth of water below the tip of the diving board in a standard public pool of 9 ft. No incidence of SCI was reported in Olympic sized public pools that meet these criteria. Most diving related SCI (DSCI) occur in residential pools where the maximum depth is less than 9 feet (Cusimano et al., 2008).

Education is seen as an important strategy for injury prevention in diving and a number of education programs (see resources) on diving safety have been implemented in North America but not evaluated for effectiveness in reducing DSCI. One educational video to schoolchildren in Slovenia noted a decrease from seven DSCI per year to two DSCI per year after 3 years of diving education. A 60-min audio-visual lecture (*ThinkFirst*) on brain and spinal cord injury prevention significantly changed students' opinions about checking the depth of swimming pools, 5 months post program. This was the only attitude that changed after the educational intervention (Falavigna et al., 2012).

In public diving facilities, more restrictive regulation on dive forms was not associated with a decrease in injuries ($p = 0.93$) (Williams & Odin, 2016). Risk was perceived to be lower for those with experience, and people with experience, favoured less regulation (Williams & Odin, 2016). An intervention (seven 10-minute sessions) to improve diving skill in inexperienced divers was successful in significantly reducing diving depth (with lesser entry angles, improved hand/arm placement, greater flight distance and steering-up manoeuvre) in different dive types, 20 months later (Blitvich, McElroy, & Blanksby, 2000). This intervention shows promise in reducing injury risk in recreational divers that dive in the same pool environment, but may not reduce the risk of serious injury when diving in oceans, lakes, rivers, etc. Future efforts should be made to develop strong evidence concerning the efficacy of such interventions in both recreational and competitive diving.

Implementation and Evaluation

Some evidence exists that evaluates the implementation of programmes to reduce injury in recreational diving, primarily aimed at school children. In an assessment and evaluation of primary prevention in spinal cord injury (Sandin & Klaas, 2013), it was found that a school-distributed educational video, *Sudden Impact (Think First),* was only viewed by an average of 16% of students in each school (Bhide, Edmonds, & Tator, 2000). There was little change in attitude and no consistent change in knowledge or behaviours as a result of the *Think First* program in high school students.

Access or exposure to the program can be a significant barrier to program effectiveness for many prevention programs, particularly those that do not own the distribution channels for their work. In general, prevention programs (from non-diving-related sources) with multimodal (including social media) components that include long-term follow-up and “booster” interventions, appear to be more effective than one-dimensional, one-time programs and act as an implementation facilitator (Sandin & Klaas, 2013).

Further work in investigating the implementation barriers for effective injury education includes a recent study by Morrongiello et al. (Morrongiello, Cox, Scott, & Sutey, 2016) that interviewed 120 children ages 7-10 years. This study evaluated the “no diving” warning signs for shallow water. Children understood that breaking your neck results in limitations in mobility and can occur from diving, but they did not anticipate that such an injury was likely to occur (Morrongiello et al., 2016). This study further highlighted that children having diving experience, biased their perceptions of injury susceptibility. Finally, Morrongiello et al. (2016) recommend using specific language toward injury risk in children (words such as ‘danger’ and being explicit in the potential for serious injury such as ‘breaking your neck’) and supervising children while at play, may reduce risky behavior in children.

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