Diving Injuries Amongst Western Australian Scuba Course Graduates

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Abstract

Introduction, Little is known about the prevalence of post-course diving injuries amongst Western Australian recreational divers, nor is it known which risk factors affect the Western Australian diver’s likelihood of sustaining a diving injury.

Objective, The aim of this study was to measure the prevalence of diving-related injuries amongst Western Australians with varying experience since certification as entry-level divers within Western Australia (WA). Specifically, the study compared divers’ experience, behaviour and equipment with their diving injury history. It was hypothesised that diving experience has an effect upon the likelihood of a certified diver suffering any of the diving injuries most commonly reported amongst international diving populations. In addition, the strength of association between diving injuries and other potential risk factors was measured amongst certified Western Australian divers.

Methods, A cross sectional survey of Western Australians, whom had completed a recognized entry-level recreational scuba diving course within WA, formed the basis of the study. Diver training facilities within WA posted a four-page questionnaire to divers they had trained to entry-level within the previous six years. The self-administered questionnaire collected data describing the divers’ post-course participation in scuba diving, injury prevalence during the last year, demographic characteristics and prevalence of known or hypothesized diving injury risk factors.

Results, A total of 500 dive course graduates returned completed questionnaires, resulting in an overall participation rate of 25%. The data were analysed using SAS, specifically for 304 active divers for whom complete data was obtained.

Ninety-four divers (30.9%) reported having suffered at least one of five types of injuries, (ear, physical, seasickness, panic or other), whilst diving during the previous year. The prevalence of reporting at least one of each type of injury was: 19.1% seasickness, 7.9% declared an ear injury, 5.3% a physical injury, 4.0% panic, and 3.6% an “other” injury.
Suffering seasickness was found to be associated with having dived inside a shipwreck, the number of medications taken within 12 hours of diving, being female and the use of a dive computer for dive planning. Risk factors associated with ear injuries were poor buoyancy control and the use of multiple methods for equalizing the middle ear space whilst descending. Physical injuries were more common amongst divers having run out of air, having dived deeper than 18m and those owning a boat. Panic was significantly associated with females. The class of “other” injuries, including lung injuries, decompression sickness and tooth squeeze, was found associated with the greater the number of dives made, females, and not carrying an alternate air source.

Overall, females were 2.55 times more likely than males to report having suffered a diving injury during the previous year (95% CI 1.45, 4.49). The number of medications taken within 12 hours of diving also increased the likelihood of reporting at least one diving injury of any type by a factor of 1.79 for each medication reported (95% CI 1.25, 2.57).

**Conclusion**, In this study diving experience, measured by the number of dives made during the previous year and the total number of dives made since certification, has not been found associated with the likelihood of reporting having suffered at least one diving injury of any type whilst diving during the previous year.

Whilst the limited response rate and self-reporting methodology threaten the validity of the findings of this study, the findings improve our understanding of the type of diving injuries commonly suffered by divers, and of which risk factors are associated with a diver’s likelihood of suffering a diving related injury within WA. These findings may assist the design of further diving injury research, ultimately leading to the design of diving safety interventions aimed at reducing the prevalence of diving injuries amongst Western Australian recreational divers.
Chapter 1
Introduction

Little is known about the popularity of diving in Western Australia (WA). A Recreational Diving Taskforce was appointed in 1999 by the Hon. Minister for Sport and Recreation, with the task of analyzing the accident and injury data for Western Australian scuba divers (1). The taskforce reported

“...there is no mechanism to collate information on dive activity, eg. Tank fills, as part of a statewide database on recreational diving in Western Australia. Preliminary research further indicated that there is no comprehensive mechanism to manage the licensing or registration of dive trainers and students within Western Australia...” (p.11)

Whilst the 1999-2000 Australian Bureau of Statistics (ABS) survey of Participation in Sport and Physical Activities estimated 30,700 Western Australians aged 15 years or more made dives that year (2), the 2002 ABS survey of Participation in Sport and Physical Activities found only 17,200 Western Australian divers had made dives during the previous year (3).

Differing methodology probably accounts for some of the estimated number of divers almost halving in two years. In 2000 people were asked, in four quarterly surveys of sports participation, to choose from a list sports they had participated in during the previous year, whereas in 2002, during autumn only, respondents recalled sports from memory without the aid of a list.

In addition to knowing little about the number of divers in WA, little is known about who they are and of the types of injuries they incur. A study of urchin divers in Maine (4), a group with many similarities to Western Australian crayfish divers, suggests barotraumas and decompression sickness (DCS) are common types of injuries we might expect to find amongst Western Australian crayfish divers. Similar findings were made by a study of recreational divers at a popular diving destination in Japan (5) and by a survey of Australian and American dive club members (6, 7).
While these injuries appear consistent amongst divers, the risk factors may be less clear. A recently published study (8) found, amongst recreational diving professionals in Sweden, no major association with the incidence of DCS related to gender, asthma, obesity, age or alcohol intake. A survey of British divers (9) investigating differences in incidence of DCS between genders found no significant links between DCS and smoking, body mass index (BMI), alcohol consumption or use of the oral contraceptive, but did find a relationship between age and DCS in males (young males had a higher incidence).

This research aims firstly to measure the frequency and nature of scuba diving injuries amongst Western Australian divers with differing levels of experience, and to identify potential risk factors associated with scuba diving related injuries amongst Western Australian recreational divers. By employing a cross sectional mail-out survey this study collected data from divers with diving experience ranging from less than one year to six years.

The study is of a history of diving injury, related to a prevalence of potential risk factors including experience, so the questionnaire collected broad data relating to the year immediately prior to participating in the study, not to the specific circumstances leading to injury. Divers were recruited into the study through the training records of dive centres/schools.

The results of the survey increase our understanding of the occurrence of scuba diving injuries suffered by Western Australians during their first six years as certified divers and will assist future public health research by identifying potential risk factors amongst divers with varying levels of experience.
Chapter 2

Background

Defining Injuries

Traditionally injuries have, at least in part, been attributed to “bad luck” or to the “will of God” (10, 11). Today, injuries are largely thought the result of the transference of energy, usually from a vector to a host, at concentrations beyond tolerable limits (11, 12). Injury may also result from the intolerable transference of energy from the host to a vector, such as in the case of frostbite, and from a host’s inability to access life sustaining elements, such as oxygen in the case of drowning (10, 13). Factors contributing to trauma were grouped according to origin by Haddon (11), and stratified by phase, as shown in figure 1.

Figure 1

The Haddon factor-phase matrix

<table>
<thead>
<tr>
<th>Human</th>
<th>Vehicle</th>
<th>Environment</th>
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<tr>
<td>Pre-event</td>
<td>1</td>
<td>2</td>
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<tr>
<td>During event</td>
<td>4</td>
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<td>Post event</td>
<td>7</td>
<td>8</td>
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<td>Results</td>
<td>10</td>
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Though designed to examine specific injury events, Haddon’s matrix may be adapted to the present study by disregarding the event-specific phase classifications, and using the factor types to classify potential risk factors for diving injury as either human behaviours and abilities, protective or injurious characteristics of dive equipment, and societal or physical environmental conditions. Other methods of classification might prove equally useful but, in the absence of a uniform system of diving injury risk factor classification, the Haddon matrix provides a useful method of organising potential risk factors and hereafter factors are classed as human, equipment or environmental.
Type of Diving Injuries

International research amongst 323 urchin divers in Maine (4) reported cases of decompression sickness, ringing ears, bleeding ears and nose, vertigo, crackling skin, hearing loss, blurred vision, double vision and/or blindness, chest pains, near drowning, mottled skin, abnormal speech, unconsciousness, temporary paralysis, joint swelling and joint pain during or following diving.

Similar results were reported by a study of recreational divers at a popular diving resort in Japan (5) which found commonly reported barotraumas of the ear (11%) and paranasal sinus (6%). Hypertension was the most commonly reported illness within a population of American divers (14), at 9.7%, followed by tinnitus (8.1%), migraine (6.0%), hearing loss (5.3%), ruptured ear drum (5.4%), unconsciousness (5.4%) and decompression sickness (2.1%), though which conditions were the result of diving was not specified (NB. hypertension and coronary heart disease are not diving related). A similar survey of 346 Australian dive club members, with four of the 29 dive clubs within WA, found 16.2% reported migraine, 12.1% tinnitus, 6.1% hypertension or coronary heart disease, 6.1% a ruptured ear drum, 3.8% hearing loss and 3.5% DCS with nerve damage (7).

Prevalence of Individual Diving Injuries

By far the most common diving disorder is middle ear squeeze (6, 15-17), and the most common injuries are those resulting from it. A prospective study of 11 experienced divers over a 15 day period, during which they averaged 41 dives each, found otoscopic evidence of middle ear barotraumas in 82% of divers by day three and 100% of divers by day 11 (18), though 41 dives in a 15 day period is extreme and the prevalence of ear barotraumas amongst divers making, for example, 41 divers per year, cannot be predicted from this study.

Middle ear squeeze occurs when the ambient pressure outside of a diver is greater than the pressure within the middle ear space, to the point where the diver feels pain and the tympanic membrane is stretched. If the diver fails to equalize the middle ear pressure with the ambient pressure, either by ascending or passing air through the Eustachian tube, and if the pressure difference continues to increase such as when descending, then
tympanic membrane rupture commonly follows (15), often resulting in vertigo. Overzealous attempts to equalise the middle ear space using the Valsalva maneuver, whereby a diver manually blocks the nose, closes the glotus, and creates a high pressure in the oral cavity, can lead to sudden increased middle ear pressure as the air suddenly passes through the Eustachian tube and into the middle ear space, forcing the oval window of the cochlea to flex inwards beyond the tolerance of the round window to flex outwards, causing round window rupture, the symptoms of which include sudden hearing loss, tinnitus and vertigo (15, 16). Vertigo is also a common symptom associated with equalisation problems during the ascent, commonly known as alternobaric vertigo (ABV) (15, 19, 20). The mechanism causing ABV is generally accepted to be unequal pressurisation of a middle ear space due to closure of a Eustachian tube, causing decreased inner ear circulation in one ear (15). The resulting pressure differential between middle ear spaces then influences the firing rate of the vestibular nerves, leading to the typical symptoms (19). Symptoms disappear if the diver reduces the difference between the pressure inside the middle ear space with the highest pressure and the ambient pressure (20), for example either by descending a metre or by closing the mouth, nose and glotus and extending the mandible, thus creating a low pressure inside the oral cavity and drawing air down the Eustachian tube. A study involving 64 sport divers found that 27% had experienced ABV (19).

Sinus squeeze is yet another diving injury caused by failure to equalize an air space during descent (6, 20), most commonly affecting the maxillary sinuses (15). Symptoms include pain and a sensation of pressure on the cheekbones or below the eyes, as the capillaries lining the sinus are engorged by the low pressure, ultimately bleeding into the sinus and followed on ascent by a bloody nasal discharge as the air within the sinus expands.

The prevalence of tooth squeeze, a painful condition caused by an air pocket within or below a tooth, has been reported as 7 cases per 10,000 dives (6).

A survey of 740 experienced Norwegian sport divers, where 40-50% had made between 100-500 dives, found 3% had been treated for DCS (21), an often painful condition caused by the formation of bubbles, mainly of nitrogen, within the body. Likewise, a study involving 3,819 Japanese divers found 1.9% of divers had suffered DCS (22).
Air bubbles may also enter the pulmonary capillary circulation if alveoli rupture due to pulmonary barotrauma (15, 16, 23). The emboli travel to the heart via the pulmonary veins and, because of the diver’s vertical position whilst ascending and the natural buoyancy of bubbles, may travel to the brain via the carotid arteries. The resulting Cerebral Arterial Gas Embolisms (CAGE) are often fatal, though not always (16). The most common symptom of CAGE is unconsciousness (20, 24), which may also be associated with DCS (25) for the same reason, though the bubble generation mechanisms may differ. Five of 39 cases of CAGE that received treatment with the help of the Divers Alert Network (DAN) during 1981 and 1982 died after surfacing and losing consciousness in the water (24). Of 866 patients treated for Decompression Illness (DCI) between 1986 and 2001 at the Hyperbaric Treatment Centre of Hawaii, 100 had Arterial Gas Embolism (AGE) while 766 had DCS (26). Aside from the acute symptoms of DCS, at least one study suggested an association between DCS with neurological consequences and long term deleterious effects such as neurological damage and/or psychiatric morbidity (27).

Pulmonary barotraumas may involve lung tissue damage, pneumothorax and mediastinal emphysema (20, 23).

Skin rash is a significant diving injury in that it is often the harbinger of more serious DCS symptoms (15). The two most common types are Erysipelas rash, varying from small papules to covering the entire chest and abdomen, and Cutis marmorata marbleization (mottling), a painful, migrating rash that often requires a few days to resolve (15). Both are thought to be caused by extravascular bubbles, a common consequence of a rapid ascent.

Headache whilst, or following, diving may be caused by a number of events including a poorly maintained regulator, poor breathing control, or a too tight wetsuit or BCD leading to hypercapnia (28), DCS (20, 24, 25, 28), limited visibility leading to acute traumatic headache (28), poorly placed compressor engine exhaust outlet elevating carbon monoxide levels in the breathing gas and leading to hypoxia (28), increased intracranial pressure due to exertion resulting in exertional headache (28), effort exertion headache, found in at least one study to be the most commonly reported sports-associated headache of four types tested for (29), migraine which may or may not be
associated with a patent foramen ovale, the so-called ice cream headache from cold water immersion (20, 28), sinus barotraumas (20), and poorly fitted regulators and/or inappropriate mouthpieces causing hyperflexation stress upon the jaw muscles resulting in temporomandibular dysfunction syndrome (30). Recurrent headaches were reported by 14.5% of Australian dive club members in an Australia-wide survey (7).

Panic is an extreme state of anxiety commonly reported by divers (31). Alfred Bove is cited as stating “panic, or ineffective behaviour in the emergency situation when fear is present, is the single biggest killer of sport divers” (32) an opinion shared by others (31). One study, of 245 divers, found that 133 (54%) had experienced panic on one or more occasions (33), with the proportion of women doing so (64%) significantly higher (p<0.05) than the proportion of men (50%). Differing definitions of panic may account for this disparity. The same study found that, of those reporting at least one episode of panic, a higher proportion of men (48%) than women (35%) considered the episode life threatening (p>0.05), despite recording remarkably similar scores on two standardized psychological questionnaires, including one designed to measure state and trait anxiety.

How commonly any of these injuries are suffered by Western Australian divers is unknown. The Queensland Dive Tourism Association reported in 1990 that there were approximately eight serious accidents per 100,000 dives (34).

**Human Factors**

**Total number of dives made**, The total number of lifetime dives was not found significantly associated with reduced risk of DCS in at least one study (8), while the number of years experience as a sport diver was found in a large UK study to be highly significantly associated with decreasing risk of DCS (35). The median number of dives for divers declaring both treated and untreated cases of DCS in a study of American members of the Divers Alert Network (DAN) was 25.2 dives (36). The inexperienced diver is widely considered more at risk of DCS than an experienced diver (37).

**Number made per year**, A study of 100 asthmatic divers in the UK found they made 12,697 dives during five years of follow up, equating to 25.4 per diver per year (38), whilst a survey of 329 divers at the Great Lakes in Michigan in 1987 found an average
of 31 dives per diver made during the previous year (39). Anonymous surveys within the British Sub-Aqua Club (BSAC) in 1976, 1980, 1986 and 1990 found the average annual number of dives made were 17.3, 18.6, 21.8 and 33.0 respectively (40). A comparison between 1,187 divers making 19,882 dives from live-aboard dive boats and 42 professional dive guides making 5050 dives from Cozumel found the dive guides suffered 8.6 times more cases of DCS than live-aboard divers (41). The researcher hypothesized that the greater number of dives made per year by the Cozumel dive guides may have been responsible for the increased incidence of DCS within this group.

Additional dive courses completed, There are several benefits for entry-level divers taking additional dive courses, including meeting more buddies, visiting new dive sites and exploring new aquatic environments, engaging in specialized dive activities and learning new dive skills (42). A 1989 study of 285 active divers in QLD found that 33% had taken additional training beyond the Open Water Diver level (43). None of the 95 trained divers also contacted in that survey, that hadn’t dived for a year or more, had completed additional courses. This is in keeping with the hypothesis that divers who complete additional training are less likely to drop-out of the sport (43), though it might equally be suggested that divers who drop out of the sport are less likely to complete additional diving education. A study of 330 Great Lakes divers in Michigan in 1987 found 42% held Advanced Open Water Diver certification, and 31% held at least one specialty (39). This continuing education level was exceeded by a study of 500 diving visitors to the Medes Islands near the Spanish Coast, which found 57% had Advanced Open Water Diver certifications (44) though the area is relatively expensive to visit and may attract older, wealthier divers. A recent e-mail survey of 12,049 certified divers by the Professional Association of Diving Instructors (PADI) found the higher a diver’s certification level the more likely the diver was still active, with 71% of Open Water Divers still active, 85% of Advanced Open Water Divers still diving and 93% of Rescue Divers (45).

Education and training have been found in at least one study to reduce the risk of DCS (8). Of the 353 recreational diver respondents to a survey of divers in the United States of America (USA), 276 (78%) were entry-level divers, 41 (12%) had Advanced Open Water and/or specialty training, 15 (4%) were assistant instructors, and 21 (6%) were
instructors(46). Of 100 asthmatic divers in the United Kingdom, 43 completed additional training during a five year follow-up period (38).

**Age**, Age is often cited as a risk factor for decompression sickness (15, 37, 47). The average age of a population of 1653 divers in the USA was reported to be 40 (SD ± 11), and ranged from 13 to 84. The average age of injured divers presenting over five years to the Accident and Emergency department of a teaching hospital located near a popular dive site in the UK was 34 years, with a range of 19-50 years (48). The average age of 3,819 Japanese divers surveyed between 1996 and 2003 was 31.4 ± 8.2 years (22), whilst the mean age for 294 tourists who tried diving during a visit to QLD was 29.2, with the range from 12 to 63 years (34). A sample of 346 active divers in QLD in 1989 had mean ages of 28.7 years for males and 27.6 years for females (49), whilst noting that most of the divers had been diving for between two and four years. The mean age of 515 Western Australian divers surveyed in 1999 was 27 years (50).

When comparing 190 divers reporting cases of decompression sickness with 1552 divers without DCS during a study of Swedish diving professionals (8), age, defined as less than 25 years old or 25 years old and older, was not found to be significant as a risk factor for DCS (95% CI for difference in proportions –0.50 to 0.44), whereas a clinical trial that involved 40 scuba divers making identical dives and being monitored for post-dive venous gas emboli (VGE), a widely used index for DCS risk, found a relationship between two bubble grades and age (p=0.49, p<0.01), and weight (p=0.46, p<0.01). Younger, slimmer divers produced less VGE than older, fatter divers (51). Though the nature of the relationship between VGE and DCS is debated, such is the relationship between VGE and “dive stress” that the British Health and Safety Executive have determined decompression procedures will no longer be evaluated according to incidence of DCS, rather they must be tested for VGE production (21).

**Gender**, The female gender has long been thought associated with a higher risk of decompression sickness (48), though the evidence hitherto does not support this opinion (8, 52). In one international study female diving professionals were, however, found more likely than men to report having suffered hearing loss and/or sinus trouble (53), and an abstract presented at the Undersea and Hyperbaric Medicine Society Annual Scientific Conference in Sydney in 2004 suggested that the patency of foramen ovale
amongst 10 female divers varied according to which stage during their menstrual cycle they were at when Transcranial Doppler Sonography was conducted upon them following injection with agitated saline (54). This interesting pilot study raises questions about the relationship between gender and DCS, though more research is needed before any firm association can be made between menstrual cycle phase and risk of DCS.

Gender distribution varies between diving populations, with the proportion of men within select populations reported as from between 62% and 69% (6, 38, 45) to as high as between 86% and 87% (8, 46), with most studies finding the proportion of males amongst groups of divers to fall within 73-76% (7, 14, 26, 35, 36, 48, 50, 55-57).

The largest study specifically aimed at gender differences between divers found the ratio of men to women varied significantly between age groups (35). Compared to men, women were found to be more likely to log their dives, to have been diving for fewer years, to make less dives requiring decompression, to have dived to shallower maximum depths, to have less often consumed alcohol within 12 hours before a dive and to be less likely to smoke. Women divers were also found to have lower BMI than the general population. A study of divers in QLD found women more likely to cite “other” reasons for not taking further diver training, including pregnancy, family commitments and injuries sustained since completing their open water diver course (43). Though not significant (p>0.05), they were also noted as more likely to cite cost as a barrier to further education.

A sample of 32 divers and 43 skiers examined for compliance to safety warnings in the USA noted no significant difference between divers and skiers, and no significant difference between genders for either how dangerous divers perceive scuba diving and skiing to be, or for the reported rates of compliance with safety warnings (58).

**Education,** A survey of Great Lakes Divers in the USA found 96% of the 367 respondents had completed high school (46) and that 76% had at least some form of college education. Interestingly 23% of the divers who dived on shipwrecks had graduated from college, whilst 41% of the non-shipwreck divers had a college degree.
Overall, 23% had a university degree, and 12% had postgraduate qualifications, which was noted as consistent with the general population.

A recent e-mail survey of 12,049 American certified divers randomly drawn from the training records of PADI found that 64% had a college degree or higher (45).

**Method of equalizing**, The most common diving injury is middle ear squeeze (15). Of the 346 Australian dive club members surveyed in the aforementioned study (7), 140 divers (40.5%) reported equalizing problems in the ears or sinuses, two of them (0.6%) even suffering round/oval window rupture.

**Medication use**, Medication use before diving is thought to potentially increase the risks associated with diving in a hyperbaric environment (47, 56), though an Australian double-blind, placebo-controlled, crossover study found the use of pseudoephedrine, a common pre-dive decongestant, was unlikely to add significant risk to divers visiting depths up to 20m (59). A similar study, conducted over the same period and using the same divers, found that a commonly taken seasickness-prevention medication adversely affected cognitive performance and, when coupled with depth, may contribute to the dangers associated with diving (60).

The pre-dive medication use reported by Australian dive club members surveyed in 2000 suggests the most common medications taken by divers are for seasickness, congestion, cardiac disease or hypertension (56).

**Smoking history**, Smokers are an “at risk” group in scuba diving (61). Typically, divers who smoke before a dive transport oxygen less efficiently, carry higher levels of carbon dioxide and carbon monoxide, (both of which are linked to headaches during and after diving), and have increased risk of inflamed mucous membranes, thus impeding a diver’s ability to equalize the middle ear spaces and increasing the risk of various audiovestibular barotraumas. Twenty-five of 94 cases of DCS treated at Okinawa were smokers, which was described as representative of the population overall (62), though the percentage of the local diving population that smoked was not stated.
A survey of 346 Australian dive club members, with four of the 29 dive clubs within WA, found 85% (n=294) were non-smokers and just 11% (n=39) smoked (7). This proportion, though it was lower than found at that time within the Western Australian population overall, is consistent with the findings of a survey of 515 Western Australian divers in 1999 (50) which similarly found the proportion of divers who smoked was less than the proportion of smokers found amongst the general population.

Alcohol intake, Alcohol consumption is often cited as a risk factor for decompression sickness (63, 64). Often the basis for this assumption is anecdotal, as is the basis for suggesting that alcohol consumption is a common problem amongst amateur divers (48, 63), though 20 out of 94 cases of DCS treated at a military hospital on Okinawa were associated with consumption of alcoholic beverages within 12 hours of diving (62). It is unknown what proportion of the non-injured diving population consumed alcohol within 12 hours of diving. A random digit dialing telephone survey of 3042 residents in Washington found that men had spent significantly more days during the previous year than women (p<0.01) engaged in activities with a high potential for submersion (boating, swimming, scuba diving) and that men were 1.29 times more likely to have consumed alcohol during the activity day (65). Men were also found to drink greater amounts of alcohol than women during aquatic activity days. These findings are consistent with the findings of a study of 1742 professionals within the recreational diving industry resident in Sweden in 1999 (8), though no significant association between weekly alcohol abuse and gender was found amongst the 190 divers reporting decompression sickness, nor was alcohol abuse found to be a significant risk factor for decompression sickness when comparing the 190 cases to the 1552 controls (OR 1.56, 95% CI 0.96-2.55). Dehydration is thought to increase nitrogen bubble formation (62), and it is the dehydrating effect of alcohol often cited as the reason alcohol consumption is listed as a risk factor for DCS, though concurrent vasodilation may also play a role (37). Even so, there is no experimental evidence that alcohol consumption itself affects a well-hydrated and well-rested diver’s susceptibility to DCS (64).

A survey of 346 Australian dive club members, with four of the 29 dive clubs in WA, found 58% had five or less drinks per week, 18% between 6 and ten drinks per week, 12% between 11 and 15 drinks per week and 12% more than 15 drinks per week (7).
**Height, weight, BMI**, A study of American divers belonging to the DAN found 43% had a BMI calculated as ideal, 40% were overweight and 14% were obese (14). Obesity is an often cited risk factor for decompression sickness (15, 47, 48), though a BMI >25 was not found to be a significant risk factor for DCS in a large study of Swedish dive professionals (8), when comparing the prevalence of DCS between 190 cases and 1552 controls. Indeed, the opposite was very nearly found significant (OR 0.74, 95% CI 0.54-1.03). A survey of 346 Australian dive club members, with four of the 29 dive clubs in WA, found that 47% were overweight (BMI>25), though dive club members are naturally older than divers entering the sport, and in this sample the mean number of years of diving equaled 10.6 ± 9.18 years (7). In WA in 1999, a survey of 515 divers found that 19% were overweight (BMI>25) and 5% were obese (BMI>30) (50).

**Equipment Factors**

**Gear ownership**, A survey of 367 divers visiting the Great Lakes in the USA during the summer of 1978 found an average investment of US$580 in dive gear (46), with those identified as shipwreck divers spending, on average, more than twice as much on dive gear as non-shipwreck divers. By 1987 the average investment in dive gear, by the 329 Great Lakes divers surveyed that year, had risen to US$2,480 (39). It is unknown how much money the average diver currently spends on dive gear as a more recent study of diving expenditure could not be found.

Diving is an equipment intensive sport. Owning a well-maintained regulator minimizes a diver’s risk of life support system failure. An analysis of 135 Australian diving incidents reported to the Royal Adelaide Hospital, 40 of which resulted in injury, found 17 of the incidents involved equipment problems and not diver error (66), most commonly problems with the regulator. Shared breathing techniques were a major cause of salt water inspiration amongst the injured, and the need for this practice is often avoided simply by carrying an alternate air source, some of which cost less just $100. Equipment was also cited as a significant risk factor for DCS in a study of 140 cases treated on the island of Saba (47), and in 17 of 94 cases treated at a military hospital on Okinawa (62).
The percentage of divers owning specific items of dive gear was ascertained in 1989, from a sample of 346 in QLD (49), to be: mask/snorkel/fins (95%), dive watch (77% for males, 57% for females), wetsuit/weightbelt (71% for males, 59% for females), BCD (47%), Regs/Gauges (46% for males, 36% for females), tank (33%) and dive computer (4%).

It is not known how the ownership of equipment is distributed amongst newly certified divers within WA, nor is it known if equipment ownership is a risk factor for specific diving injuries such as ruptured ear drums, which may result from uncontrolled changes in pressure.

**Diving behaviors**, Decompression sickness in divers, as previously described, is caused by too rapid an ascent to the surface. During the ascent VGE form and are carried to the alveoli whence they are exhaled (25). If the ascent is too rapid then the alveoli may be overwhelmed and bubbles enter the arterial circulation. In addition, autochthonous bubbles may form elsewhere within the diver. To allow sufficient time for gas to move from tissue to blood and then to the lungs, divers follow diving tables of time versus depth. In recent years an increasing number of divers use dive computers (62), which are essentially electronic versions of the algorithms used to calculate the analog tables. Though many divers have been stricken with DCS following dives made within the time limits prescribed by the tables or dive computer for whichever depth they have been diving to (37, 47, 62), any diver making unplanned dives must surely be at increased risk of DCS, in the same manner as the driver of a car without a speedometer is at increased risk of a speeding fine. Twenty-four of 94 cases of DCS treated at a military hospital on Okinawa involved exceeding the accepted limits, based upon United States Navy (USN) standard air decompression tables), whilst 18 of the 94 involved no apparent risk factors for DCS (62). Of the 122 cases of DCS treated on Saba between January 1999 and August 2000, more than 50% were classed as “undeserved” because the divers had not exceeded the limits of accepted dive tables (37). Despite the increased risk, many divers cease planning their dives using tables once they are certified and, with the passage of time, lose this important skill.

**Multiple ascents**, The number of dives made in succession is a known risk factor for decompression sickness (48). Multiple ascents, known as “yo-yo dives” and “bounce
“diving” were implicated in 8 out of 94 cases of DCS treated at a US military base on Okinawa (62).

Running out of air, Of 515 Western Australian scuba divers returning completed diver questionnaires in 1999, 91 (19.0%) reported unexpectedly discovering they were low on air and 20 (3.7%) reported ascending urgently because they had run out of air (50).

Environmental Factors

Diving solo, Scuba diving is often associated with sensation seeking (67-69) and, despite the sport’s enviable safety record, is widely perceived as high-risk or dangerous (7, 33, 58, 70-73). Risk taking is closely associated with injury in sport diving (74). The majority of diver training organisations recommend diving with a buddy, and dissuade divers from diving alone. A review of 821 diving fatalities occurring between 1992-2001 recorded by DAN noted that nearly one in five fatalities involved divers who entered the water unaccompanied, while an even greater percentage involved divers who had become separated during the dive (75). It was also noted that many of the deaths occurred where a buddy may have changed the outcome, for example when a diver ran out of air or became entangled. Of 100 asthmatic divers surveyed in the UK, 37 declared they’d shared air at some time during their diving career (38). Of the 515 Western Australian divers surveyed in 1999, most of whom had made far fewer dives than the British asthmatic divers, 19% had unexpectedly run low on air and 4% had made emergency ascents to the surface because of perceived air supply failure (50). Choosing to dive alone is, for the recreational diver, widely seen as accepting an inherently greater level of risk (37).

Maximum depth in last 12 months, The maximum preferred depth for 367 divers visiting the Great Lakes in the USA was 15m for 33% of the divers, 30m for 51%, 45m for 15% and 2% preferred going beyond 45m (46). A survey of 329 divers in Michigan in 1987 found an average length of experience of 9.4 years (39), and preferred maximum dive site depths of 0-15m (12%), 15-30m (49%), 30-45m (32%) and greater than 45m (7%). One would expect the maximum depths reached during the previous year to be shallower for less experienced divers.
Motivation for diving, Though many popular outdoor sports are family oriented, scuba diving is not one of them. A survey of artificial reef divers in Texas found just 13% of respondents listed family members as the social group with whom they dive most often (55). They reported participating in night diving (81%), underwater photography (53%), wreck diving (52%) and spear fishing (26%).

A survey of visitors to coral reefs in St Lucia noted that 15% of divers were photographers (57), with 9% dedicated to underwater photography and 6% using point-and-shoot cameras. Reasons for engaging in scuba diving were examined amongst eight disabled and eight able-bodied divers, with excitement, fun, facing challenges and the ability to improve skills rated highly for both groups (76). The least favoured reasons for diving were for the enjoyment of professional instruction and, unanimously, to please others or to feel needed by others. It would seem the motivation to dive is most commonly intrinsic or selfish, and less likely to result from relationships established during participation. This may express itself in a number of ways, including diving alone and/or diving with a specific purpose in mind over the purpose of enjoying the activity with someone specific. At least one study, of 30 Australian scuba divers, found divers more likely than the reference population to score highly on the Sensation Seeking Scale, particularly in the areas of seeking thrill, adventure and sensation, and lower than the reference population when it came to boredom susceptibility and disinhibition (69).

In WA diving for crayfish is a popular pastime, indeed Fisheries WA issued 40,000 crayfish licenses during 2002 (Burrows, R. personal communication), many of them to divers. Though a study of the diving practices of Western Australian crayfish harvesters could not be found, Miskito Indian diving lobster harvesters were found to both regularly exceed accepted safe time-depth limits and to have an unusually high incidence of DCS (77), as were Alaskan diving harvesters (78), the sea urchin harvesters of Maine (4), Puerto Rican seafood divers diving for lobster, conch and fish (79), Filipino fishermen divers (80) and sea-cucumber harvesters of the Galapagos Islands (81).

Charter boat diving, Commercial dive charter boats are covered by the WA Diving and Snorkeling Code of Practice, whereas public dive platforms, such as beaches and non-
commercial boats, are not, unless dive instruction for commercial reward is underway (82). Accordingly, charter boats have well-trained crew, search and rescue equipment, first-aid facilities, the crew make shrewd assessments of each dive site and in every respect the dive is often better planned and equipped than similar dives made from recreational craft. One study of adherence to warnings examined the behavior of 32 scuba divers diving from either a commercial charter boat or from a public beach in America (58). The following quote encapsulates the situation that also exists in WA:

“The dive boats required that all divers sign a warning/waiver prior to diving. They also required that everyone show their certification cards to indicate proof of training. After roll call and before the first dive, the dive master or boat captain gave a briefing about the dive conditions and the boat safety rules. La Jolla Cove (the beach dive) also had signs posted with the safety rules and water conditions, but there were no release forms or verbal instructions as this area was a public dive area and not a private dive boat.” (p. 125).

This describes the choice divers make in WA, when choosing between catching a charter boat out to the end of the Busselton Jetty or walking out along the jetty to the public dive platform. With the former, an expert assesses the situation, forms a well thought out dive plan and is prepared for emergencies. In the latter the often inexperienced or untrained diver does the best he or she can or thinks necessary, whichever is the lesser. In this respect commercial charter boat trips often act as “mini refresher” experiences, where divers are reminded how to plan and conduct safe dives. An observational study of 192 divers preparing to dive near an island located at the outer Great Barrier Reef recorded, over six months, unsafe practices witnessed at the surface, including assembling the equipment incorrectly, entering the water without the air turned on and returning to the boat low on air (83).

How frequently Western Australian divers take a dive trip aboard a commercial charter boat is unknown. A survey of divers in Queensland found 51% of the sample had made more than 90% of their dives from commercial charter boats (49).

With the increased popularity in recent years of deliberately scuttled dive wrecks near the WA coast, known as Artificial Reefs, it is noteworthy that of 367 divers visiting the Great Lakes in the USA, 71% of those identified as shipwreck divers said they had
chartered a boat whereas just 38% of those identified as non-shipwreck divers had chartered a boat (46). In Texas, 461 divers destined for an artificial reef aboard a commercial boat reported making, on average, four dives per diver from charter boats during the previous year (55). It is possible that divers who have visited a shipwreck from a charter boat within the previous year may have fewer so-called “bad habits”, such as entering the water without the air turned on, than divers who are self sufficient.

A survey of diving visitors to the Thunder Bay Preserve in Michigan in 1986 found 67% made dives from charter boats during their first visit, while just 57% used charter boats during repeat visits (84). The same survey found just 25% of first-time visitors used private craft, whilst 39% of repeat visitors used private craft. Similar surveys of diving visitors to the Alger Bottomland Preserves in Michigan between 1984 and 1986 inclusive found that 54% of first-time visitors and 48% of repeat visitors used a charter boat to dive from, whilst just 18% of first time visitors dived from private vessels, compared with 44% of repeat visitors (85). Similar findings were made elsewhere in Michigan in 1986, with repeat divers making fewer charter boat dives than first-time visitors (84). These studies suggest a possible link between the desire to visit a shipwreck and taking a commercial charter, and the possibility that once divers have experienced where to go with a professional charter then they are more likely to dive from a private vessel when they return.

*Uncontrolled ascent,* The main risk factor for barotraumas is rapid ascent (48), as often happens during an uncontrolled ascent. Panic is often blamed for the diver making a rapid ascent (33), and one study reported as many as 11 out of a group of 42 people learning to dive suffered panic during their dive course (86).

**Brief Summary and Rationale for Study**

**Summary,** The prevalence of each type of diving injury amongst Western Australian divers is unknown, as is the prevalence of risk factors found associated with injury amongst other diving populations.

**Aim,** The aim of the project is to estimate the type and prevalence of diving injuries amongst recreational scuba divers who have completed entry-level training within WA
during the six years prior to the survey, and to investigate potential risk factors for the most common of these recreational diving injuries. Entry-level is the generic descriptor for levels of certification enabling divers to rent scuba gear, purchase air fills and to plan repetitive single-depth air dives during daylight in open water, to depths no greater than 18m, with a buddy, in conditions similar to those in which they were trained.

**Objectives,**

- Measure the prevalence of a history of diving-related injuries amongst Western Australians with varying levels of experience since certification as entry-level divers within WA.

- Identify potential risk factors associated with diving related injuries amongst Western Australian divers, such as equipment ownership, diving behavior, gender and medication use.
Chapter 3
Methods

Research Design
A cross sectional survey of Western Australians whom have completed a recognized entry-level recreational scuba diving course within the last six years in WA formed the basis of the study. These dive course graduates completed a self-administered questionnaire that gathered data on the divers’ continued participation in scuba diving, injury prevalence during the last year, demographic characteristics and prevalence of known or hypothesized diving injury risk factors. The research was approved by the University of Western Australia (UWA) Human Research Ethics Committee.

Diving population, The number of trained divers living in WA is unknown. The 2000 Participation in Sport survey conducted by the ABS estimated there were 30,700 active divers with WA at that time (2). It is not known how many divers have been trained within WA since then, nor is it known how many Western Australians have learned to dive whilst outside of the state. Similarly, it is neither known how many trained divers have left WA nor how many have moved into WA since that survey.

In 2003 PADI issued 8,900 certifications within WA (87) whilst Scuba Schools International (SSI) issued 415 (Condon, J., by e-mail, 16th August 2005). It is thought that approximately half these certifications were issued for entry-level training though how many of these were issued to visitors to WA is unknown. It is also unknown if any other training cadre certify entry-level divers within WA but if they do then they do so without advertising in telephone directories and, as such, are assumed to certify a relatively small proportion of new divers within WA each year. The number of recreational divers trained within WA by instructors who do not advertise in telephone directories is, similarly, unrecorded. Again, it has to be assumed that the majority of divers trained within WA learn to dive at commercial dive schools and clubs that advertise diver training.

Therefore, within WA it is thought there are at least 30,000 active divers, that possibly 5000 new divers are trained here each year, many of them tourists, and that many Western Australians learn to dive whilst outside of WA.
The proportion of the Western Australian diving population that stops diving each year is, again, unknown. There are 25% fewer diving business advertising in the Western Australian business telephone directories in 2005 than there were a decade earlier (88-95), suggesting the possibilities that either diver participation, or the diving population, may be in decline, though external market forces such as the value of the Australian dollar, rising insurance premiums and the collapse of the state’s domestic airline may have contributed to Western Australian dive business closures in recent years.

In short, little is known about the size of this discrete population.

**Diver trainer population,** Sixty-eight businesses were listed under the headings “Divers Recreational” and/or “Divers Equipment and Supplies” in the four issues of the business telephone directory current in WA at the commencement of the study (92-95). Thirty-nine of the sixty-eight identified themselves as diver training facilities when contacted by telephone.

**Survey instrument,** The survey instrument consisted of 29-questions and was designed for self-administration. The first page consisted of an assessment of the diver’s experience in time and number of dives, gear ownership, level of training and diving practices. The second page covered diving activity during the twelve months prior to the survey, the third page addressed recent diving-related injuries and pre-dive medication use. The last page surveyed diver demographics and behaviors such as smoking status and weekly alcohol consumption. To assure anonymity neither name nor address was collected. The questionnaire is attached as appendix three.

Cross sectional surveys are used widely to measure the prevalence of diving-specific injuries within populations of divers. Prior to constructing this instrument, questionnaires used within WA (6) and overseas (22, 32, 38, 53, 96) were obtained, yet none was entirely satisfactory for use within WA in this instance. Each question within each questionnaire was considered for relevance to the present study and like variables were grouped according to type, for example, demography, injury history, etc. Additional criteria identified during the literature search, such as particular risk factors and diving behaviors, were added to the list of potential items for inclusion, whilst the
least commonly reported diving injuries were removed from the list of possibilities to be assessed by the survey questionnaire.

**Instrument validity**, A working draft-questionnaire was given to three dive centre owners/managers, three diving instructors, two psychologists, two public health researchers and two of the diving experts listed by SPUMS as knowledgeable of diving injuries (97). Each person completed the survey and commented upon the face and content validity of each question. With their input, additional questions specific to WA were added, for example whether a diver owns a boat or dives to hunt for crayfish. Finally, once the face and content validity were judged satisfactory, the revised draft version was pilot tested.

**Pilot testing**, The revised questionnaire was pilot tested with twenty resident Western Australian recreational divers that had learned to scuba dive outside of WA, but who were thought no different to the target population in any other respect. Each diver was given a copy of the draft version, draft information letter and a stamped addressed envelope for the questionnaire’s return. Three weeks later 16 of the questionnaires (80%) had been returned. Eight of the divers were contacted by telephone and asked questions about the instrument adapted from the “Checklist For Pilot Testing” (98). Following this further, minor, refinements were made to the instrument’s form and presentation, for example the potential for ambiguity was further reduced by defining an ascent as “(to the surface).” The finished version was then mailed out to test its reliability.

**Reliability**, The questionnaire was posted to twenty two university dive club members in New South Wales and Tasmania. Three weeks later a second, identical questionnaire was posted to these same divers to complete. Returned first and second questionnaires were matched in pairs, by matching the postcode, month and year of birth, and gender for each.

Unfortunately, the number of questionnaires returned, even after repeated follow-up, was just 15 out of 44 (34%), and of those completed by the same divers twice (n=4) there was 100% agreement between first and second questionnaires. Therefore, it was
not possible to measure the reliability of the questionnaire using correlation coefficients and kappa.

Further investigation suggested that continued efforts to encourage volunteers to return second completed questionnaires would be unlikely to improve upon the 9% test-retest participation rate. The time and money constraints of this study prevented offering suitable incentives to encourage a higher participation rate and, without suitable incentives, it appeared unlikely that an accurate reflection of the instrument’s reliability would be determined if additional dive clubs were recruited.

Therefore, initial measurement of the reliability of the instrument appeared encouraging but the participation rate was poor.

**Recruitment, In the first instance each diver training facility was mailed a copy of the questionnaire with a letter describing the project and requesting they participate by forwarding on questionnaires to divers they had trained to entry-level within the previous six years. This was followed up with a telephone call, if needed. If the owner or manager was unavailable at the time of the call then a time to re-try was agreed, sometimes weeks later. As each dive centre agreed to address surveys to their customers the enveloped questionnaires were delivered, either in person or by post. By the time all but seven dive centres had nominated if they would take part, the predetermined goal of 2000 surveys mailed had been exceeded and so the last seven dive centres were not again requested to participate. Of the 32 businesses successfully contacted five had closed or were in the process of liquidation. Of the 27 remaining businesses five refused to participate and 22 agreed, resulting in an overall dive school participation rate of 63%, as shown in table 1.
Table 1

Dive school participation rate by statistical division

<table>
<thead>
<tr>
<th>Statistical Division</th>
<th>No. of Dive Schools</th>
<th>No. Participated</th>
<th>Participation Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>South East</td>
<td>1</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Lower Great Southern</td>
<td>4</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>South West</td>
<td>7</td>
<td>7</td>
<td>100</td>
</tr>
<tr>
<td>Perth</td>
<td>14</td>
<td>9</td>
<td>64</td>
</tr>
<tr>
<td>Central</td>
<td>5</td>
<td>2</td>
<td>40</td>
</tr>
<tr>
<td>Pilbara</td>
<td>2</td>
<td>1</td>
<td>50</td>
</tr>
<tr>
<td>Kimberley</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>35</td>
<td>22</td>
<td><strong>63%</strong></td>
</tr>
</tbody>
</table>

As can be seen in table 1, the dive school participation rate north of Perth (three out of eight, 38%) was much lower than that of the dive schools south of Perth (10 out of 12, 83%).

**Inclusion criteria,** Each dive school addressed the questionnaires to certified recreational divers who lived in WA and who had completed their entry-level diving course at that dive school before April 1st 2005. Because of their widely different types of exposure, (different dive profiles), commercial and technical divers trained within WA were excluded, unless they had completed an entry-level recreational scuba diving course during the study period. Divers not certified by a training organisation belonging to the *Recreational Scuba Training Council* (RSTC), such as self-taught divers, were also excluded, as were divers who reside outside of WA (tourists).

**Study sample,** One hundred and sixty-seven surveys (8%) were sent to divers trained by instructors licensed by SSI whilst the remaining 1910 (92%) went to divers certified by instructors belonging to PADI. The questionnaires were accompanied by a letter describing why the survey was being conducted, conditions of confidentiality and what would happen to the returned information. This letter is attached as appendix two.
In total, between January and April 2005, 2077 questionnaires were addressed by diver training facilities to divers, (with postal addresses within WA), that had completed an entry-level dive course at these dive schools. Of these, 97 were returned to sender unopened and 505 were returned completed. Of these 505, six were completed by ineligible divers, leaving 499 out of 1974 completed anonymously by the target population, a participation rate of 25%, apportioned across the state as shown in table 2.

Table 2
Distribution of respondent divers by statistical division

<table>
<thead>
<tr>
<th>Statistical Division</th>
<th>Number Sent (n)</th>
<th>Number Returned (n)</th>
<th>Response Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>South East</td>
<td>50</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Lower Great Southern</td>
<td>85</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>South West</td>
<td>1164</td>
<td>227</td>
<td>20</td>
</tr>
<tr>
<td>Perth</td>
<td>684</td>
<td>198</td>
<td>29</td>
</tr>
<tr>
<td>Central</td>
<td>30</td>
<td>12</td>
<td>40</td>
</tr>
<tr>
<td>Pilbara</td>
<td>64</td>
<td>21</td>
<td>33</td>
</tr>
<tr>
<td>Kimberley</td>
<td>0</td>
<td>5</td>
<td>∞</td>
</tr>
</tbody>
</table>

Note: Sender’s district determined by dive school location, respondent’s district determined by postcode.

Data Collection

Each questionnaire was accompanied by a reply-paid envelope addressed to the researcher at UWA. Completed surveys were returned in these reply-paid envelopes. Undelivered surveys were returned to the researcher via the postal system, marked “Return-to-Sender”.

At least one dive school owner expressed concern about writing to his customers twice in a single month, in addition to the usual promotional mail-out. As the surveys were anonymous it would not be known which divers had responded, meaning reminder letters, if sent, would need to be addressed to all divers and so, in addition to potentially bothering the customers, each dive school would need to either supply a list of their customer’s details to the researcher or else address twice as many envelopes, often, by hand.
Following discussions between the researcher and three dive school managers, it appeared either scenario was likely to significantly reduce the participation rate of dive schools so the decision was made to post the questionnaire and information letter to each diver, without reminder letters to follow. The effect this has had upon the non-response bias in this case, with a response rate of just 25%, is unknown though reminder letters are an effective method of increasing response rate (99) and mail survey non-responders are often biased toward education, (which relates to income), and interest, (which is associated with frequency of participation). Mail surveys with returns of between 20 and 30 percent often produce data that is not representative of the sampled population (99, 100).

The returned questionnaires were opened in groups of fifty and entered into the database in no particular order. Each questionnaire was assigned a consecutive index number that was noted on the top right corner of the questionnaire. In this way any string of data can be re-matched with the original questionnaires from which they came.

Data Analysis

The data returned by the 500 eligible divers were organised using Microsoft Excel and analysed using SAS (101). Right skewed categorical variables were collapsed using the substantive approach (100). For example, the number of items of dive gear owned by divers was classed as either two or less items, or more than two items. Right skewed continuous variables, such as the length of time between certification as a diver and the last dive made, were logistically transformed using the natural logarithm, and in each case this redistributed the data to an approximately normal distribution.

Respondents were designated as active divers if they had made a dive within the previous year. A count of the number of missing data was made for each independent variable, and variables with the highest number of missing observations were removed from the data set, till a sample of 304 active divers remained, for whom complete data for all independent variables were known. This sample was used both for univariate analysis and, ultimately, for logistic regression modelling to investigate the association between experience and diving injury.
In all cases the outcome variables were whether or not a diver had suffered a diving injury. For binary dependent variables the strength of association was measured using a chi-square test with one degree of freedom. For continuous variables the strength of association was measured using t-tests, with 302 degrees of freedom where the variance did not significantly differ between injured and uninjured divers.

During the logistic regression, backwards elimination was used to remove least significant variables till those remaining were significant to at least $p=0.05$. Only those variables for which expected cell counts exceeded five were included in each model, and this varied between injury types. For example, the number of cases of panic ($n=12$) was such that ownership of a boat divided the injured divers in such a way that the expected count in at least one cell fell below 5, and so this variable was not included in the logistic regression model for panic. However, for the larger set of reported cases of seasickness ($n=58$,) the distribution was such that all cells exceeded five and so boat ownership was tested for association with seasickness.

In all cases diving experience, measured by both number of lifetime dives and number of dives during the previous year, were included, and cell counts for divers having suffered at least one injury of any type ($n=94$) were high enough for all variables to be included in the final model. In this respect, wherever a level of significance is reported for a binary variable then all cell counts exceeded five, and where significant associations are noted following logistic regression then the fit of each model was valid.

Likely interactions were tested for, such as for between ownership of a BCD and a loss of buoyancy control during the previous year. Where significant interactions are noted, the measure of the strength of association reported is a chi-square test.
Chapter 4

Results

The questionnaire examined diving injuries that had occurred during the year prior to participating in the survey. From a total of 499 respondents to the survey, 445 reported making at least one dive during the previous year, with 304 having complete survey data. This chapter summarises the results for these “active” divers.

Firstly the characteristics of the divers are described, followed by a description of the injuries that were reported. The reported prevalence of risk factors is then presented, as either human, equipment or societal/environmental factors, and the strength of the relationship between each risk factor and each reported injury is described. A summary table is presented for each group of factors. Finally, the relationship between these factors is examined as they are fitted to a linear regression model for each type of injury.

Diver Characteristics

The majority of active divers, (n=227, 75%) were male, with mean ages at certification of 32.9 (± 10.9) for males and 30.7 (± 10.6) years for females. The mean date of entry-level course completion was July 2003 (± 1.5 years) and the median length of time divers reported between earning their first diver certification and making their most recent dive was 1.2 years. Divers with at least one year of diving experience since completing the entry-level course (n=186) reported a median of 18.9 dives per year, whilst the median number of dives per year overall, including divers with less than one full year since certification (n=118), was 12.0.

One third (n=107, 35%) of active divers had completed at least one additional diver course and less than one third of those (n=30) had completed two or more additional dive courses. Participants reported owning a mean of 4.7 items of dive gear (± 2.2). Forty-five divers (14.8%) made dives outside of WA during the previous year, and 178 divers (59%) made at least one of the previous year’s dives from a charter boat. The mean number of ascents made to the surface in any one day of diving during the previous year was 2.6 (± 1.4).
One in four divers (n=75) reported taking at least one of four listed types of medication within 12 hours of diving, the median number of alcoholic drinks consumed per week was 6.0 per diver and 8% of the respondents (n=23) were smokers.

Ninety percent of respondents (n=272) usually used scuba, 8% (n=24) reported usually preferring surface supplied breathing apparatus (SSBA), known locally as “hookah” diving. In the spirit of adventure that is typical of Western Australians 101 divers (33%) claimed to have dived inside a cave during the previous year, 139 divers (46%) had dived inside a shipwreck and 86 divers (28%) had dived at night.

Hunting whilst diving is popular in Western Australia, with 182 divers (60%) being motivated to dive during the previous year by the prospect of catching a crayfish. Twenty-five divers (8%) went diving in search of abalone and 64 divers (21%) went diving armed with spearguns.

Nine percent of divers (n=28) claimed to have lost buoyancy control and made an uncontrolled ascent to the surface during the previous year, 28 divers (9%) shared air with a buddy during the year, and 20 (7%) had run out of air and made for the surface.

Twenty-one percent of divers (n=63) reported not having finished Year 12 education, another 20% (n=61) reported Year 12 to be their highest completed level, 19% (n=57) had completed a trade, 11% (n=34) a diploma, 20% (n=62) a university degree and 9% (n=27) had post-graduate qualifications. In keeping with the high rate of private boat ownership amongst Western Australians, 123 divers (40%) reported owning a boat, and 157 divers (52%) reported having at least one other diver within their immediate family.

**Injuries**

Due to the low prevalence of some injuries, as shown in table 3, and sample size limitations, the data were grouped into broad injury types of meaningful size, according to the similarity of their sequelae. Ruptured ear drums, vertigo/dizziness, tinnitus, hearing loss and/or ear/sinus surgery were grouped as Ear Injuries, as each often begins with a pressure difference between either ear or sinus air-filled cavities and the ambient pressure underwater. Blotchy or itchy skin, often associated with decompression
sickness, cases of decompression sickness and physical injury (e.g. fractures/cuts) were grouped as *Physical Injuries*, being as they were the injuries most likely avoided by planning and preparation. Tooth squeeze, lung injuries, unconsciousness and/or other (free format) were grouped as *Other Injuries*, being as they were considered the least avoidable through planning and preparation. Panic and seasickness were treated separately to the other injuries, as these are considered states resulting from extremes in anxiety or motion, often associated with subsequent injury yet not defined as injuries themselves. Due to their distinction as individual states of health, and their close association with injury, the associations between panic or seasickness and potential risk factors for injury were also investigated and, for brevity, hereafter the inclusion of panic and seasickness is implied when reference is made to, for example, “a diving injury any type”. The number of divers reporting at least one of these types of injuries, (that occurred whilst diving during the previous 12 months), is presented in table 3:

### Table 3

**Prevalence of diving injuries**

<table>
<thead>
<tr>
<th>Injury</th>
<th>n</th>
<th>%</th>
<th>Type</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ruptured ear drums</td>
<td>2</td>
<td>0.7</td>
<td>Ear injuries</td>
<td>24</td>
<td>7.9</td>
</tr>
<tr>
<td>Vertigo/dizziness</td>
<td>13</td>
<td>4.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tinnitus</td>
<td>4</td>
<td>1.3</td>
<td>Physical injuries</td>
<td>16</td>
<td>5.3</td>
</tr>
<tr>
<td>Hearing loss</td>
<td>9</td>
<td>3.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ear/sinus surgery</td>
<td>1</td>
<td>0.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blotchy/itchy skin</td>
<td>5</td>
<td>1.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decompression sickness</td>
<td>3</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical injuries</td>
<td>11</td>
<td>3.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panic</td>
<td>12</td>
<td>4.0</td>
<td>Panic</td>
<td>12</td>
<td>4.0</td>
</tr>
<tr>
<td>Sealsickness</td>
<td>58</td>
<td>19.1</td>
<td></td>
<td>58</td>
<td>19.1</td>
</tr>
<tr>
<td>Tooth squeeze</td>
<td>4</td>
<td>1.3</td>
<td>Other injuries</td>
<td>11</td>
<td>3.6</td>
</tr>
<tr>
<td>Lung injuries</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unconsciousness</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (free format)</td>
<td>8</td>
<td>2.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any diving injury</td>
<td>94</td>
<td>30.9</td>
<td></td>
<td>94</td>
<td>30.9</td>
</tr>
</tbody>
</table>
Risk Factors

In keeping with Haddon’s Risk Factor Matrix for Injuries, potential risk factors for diving injuries were grouped into three categories; Human, Equipment or Societal/Environmental Factors. In accordance with the findings of other diver surveys, each category of risk factors were then further divided into Major Factors and Minor Factors, depending upon the anticipated likelihood of an association between each factor and any of the types of diving injuries. The major and minor factors of each of the three types of injury are presented separately and then summarised in table form.

Major Human Factors

Number of dives, The median number of dives made by divers making at least one dive since completing an entry level diving course, stratified by injury type, is presented in table 4, for both injured and uninjured divers. Amongst non-injured divers the median number of dives was 20.0 irrespective of the median number of dives made by injured divers.

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>Median number of lifetime dives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Injured</td>
</tr>
<tr>
<td>Ear injuries</td>
<td>18.0</td>
</tr>
<tr>
<td>Physical injuries</td>
<td>36.0</td>
</tr>
<tr>
<td>Panic</td>
<td>13.0</td>
</tr>
<tr>
<td>Seasickness</td>
<td>20.0</td>
</tr>
<tr>
<td>Other injuries</td>
<td>35.0</td>
</tr>
<tr>
<td>Any diving injury</td>
<td>20.0</td>
</tr>
</tbody>
</table>

The number of dives made by divers making at least one dive since completing entry-level training was not found to be significantly associated with the likelihood of reporting an ear injury (p=0.30), physical injury (p=0.14), panic (p=0.20), seasickness (p=0.98), an other diving injury (p=0.13) or any diving injury (p=0.61). However, females were found more likely to report ear injuries the fewer dives they had made since certification (p=0.02).
The median number of dives made during the previous year by divers making at least one dive during the year prior to completing the questionnaire, stratified by injury type, is presented in table 5, for both injured and uninjured divers. Amongst non-injured divers the median number of dives made during the previous year was 12.0 irrespective of the median number of dives made by injured divers.

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>Median number of dives made during the previous year</th>
<th>n</th>
<th>Median number of dives made during the previous year</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ear injuries</td>
<td>11.0</td>
<td>24</td>
<td>12.0</td>
<td>280</td>
</tr>
<tr>
<td>Physical injuries</td>
<td>20.0</td>
<td>16</td>
<td>12.0</td>
<td>288</td>
</tr>
<tr>
<td>Panic</td>
<td>6.5</td>
<td>12</td>
<td>12.0</td>
<td>292</td>
</tr>
<tr>
<td>Seasickness</td>
<td>12.0</td>
<td>58</td>
<td>12.0</td>
<td>246</td>
</tr>
<tr>
<td>Other injuries</td>
<td>20.0</td>
<td>11</td>
<td>12.0</td>
<td>293</td>
</tr>
<tr>
<td>Any diving injury</td>
<td>14.5</td>
<td>94</td>
<td>12.0</td>
<td>210</td>
</tr>
</tbody>
</table>

The number of dives made by divers making at least one dive during the previous year alone was not found to be significantly associated with the likelihood of reporting an ear injury (p=0.75), physical injury (p=0.09), panic (p=0.31), seasickness (p=0.36), or a diving injury of any type (p=0.12), but was associated with an other diving injury (p=0.03).

The median number of dives made per year by divers with at least one year since completing an entry level diving course (n=186) and whom had made at least one dive during the previous year, stratified by injury type, is presented in table 6, for both injured and uninjured divers.
Table 6
Median number of dives made per year by injury type

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>Median number of dives per year since certification</th>
<th>Injured</th>
<th>n</th>
<th>Not injured</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ear injuries</td>
<td></td>
<td>18.5</td>
<td>13</td>
<td>19.1</td>
<td>173</td>
</tr>
<tr>
<td>Physical injuries</td>
<td></td>
<td>18.6</td>
<td>10</td>
<td>18.9</td>
<td>176</td>
</tr>
<tr>
<td>Panic</td>
<td></td>
<td>14.0</td>
<td>6</td>
<td>18.9</td>
<td>180</td>
</tr>
<tr>
<td>Seasickness</td>
<td></td>
<td>16.2</td>
<td>36</td>
<td>20.0</td>
<td>150</td>
</tr>
<tr>
<td>Other injuries</td>
<td></td>
<td>41.8</td>
<td>8</td>
<td>18.5</td>
<td>178</td>
</tr>
<tr>
<td>Any diving injury</td>
<td></td>
<td>16.7</td>
<td>61</td>
<td>20.0</td>
<td>125</td>
</tr>
</tbody>
</table>

The number of dives made per year between the date first certified at entry-level and the date the most recent was made, for divers with at least one year since being certified as an entry level diver, was not found to be significantly associated with the likelihood of reporting an ear injury (p=0.97), physical injury (p=0.72), panic (p=0.63), seasickness (p=0.94), an other diving injury (p=0.06) or a diving injury of any type (p=0.79).

Time since certified, The median length of time since completing an entry level diving course for divers whom have made at least one dive, stratified by injury type, is presented in table 7, for both injured and uninjured divers.

Table 7
Median length of time since certified as a diver by injury type

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>Median length of time since certification (years)</th>
<th>Injured</th>
<th>n</th>
<th>Not injured</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ear injuries</td>
<td></td>
<td>1.0</td>
<td>24</td>
<td>1.2</td>
<td>280</td>
</tr>
<tr>
<td>Physical injuries</td>
<td></td>
<td>1.1</td>
<td>16</td>
<td>1.2</td>
<td>288</td>
</tr>
<tr>
<td>Panic</td>
<td></td>
<td>0.7</td>
<td>12</td>
<td>1.2</td>
<td>292</td>
</tr>
<tr>
<td>Seasickness</td>
<td></td>
<td>1.1</td>
<td>58</td>
<td>1.2</td>
<td>246</td>
</tr>
<tr>
<td>Other injuries</td>
<td></td>
<td>1.3</td>
<td>11</td>
<td>1.2</td>
<td>293</td>
</tr>
<tr>
<td>Any diving injury</td>
<td></td>
<td>1.1</td>
<td>94</td>
<td>1.2</td>
<td>210</td>
</tr>
</tbody>
</table>
The length of time between completing entry-level training and each diver’s most recent dive, for divers whom have made at least one dive during the previous year, was not found to be significantly associated with the likelihood of reporting an ear injury (p=0.08), a physical injury (p=0.76), panic (p=0.27), seasickness (p=0.56), an other diving injury (p=0.83) or any diving injury (p=0.67).

**Additional training,** Divers were asked if they had completed additional diver training since completing entry-level training, and were categorised as either having completed additional training, or not having completed additional training. The percentage of injured, and uninjured, divers reporting to have completed at least one additional course is presented in table 8.

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>% of injured completed additional training</th>
<th>n completed additional training / n injured</th>
<th>% not injured completed additional training</th>
<th>n completed additional training / n not injured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ear injuries</td>
<td>41.7</td>
<td>10 / 24</td>
<td>34.6</td>
<td>97 / 280</td>
</tr>
<tr>
<td>Physical injuries</td>
<td>37.5</td>
<td>6 / 16</td>
<td>35.1</td>
<td>101 / 288</td>
</tr>
<tr>
<td>Panic</td>
<td>16.7</td>
<td>2 / 12</td>
<td>36.0</td>
<td>105 / 292</td>
</tr>
<tr>
<td>Seasickness</td>
<td>44.8</td>
<td>26 / 58</td>
<td>32.9</td>
<td>81 / 246</td>
</tr>
<tr>
<td>Other injuries</td>
<td>36.4</td>
<td>4 / 11</td>
<td>35.1</td>
<td>103 / 293</td>
</tr>
<tr>
<td>Any diving injury</td>
<td>38.3</td>
<td>36 / 94</td>
<td>33.8</td>
<td>71 / 210</td>
</tr>
</tbody>
</table>

The effect of having completed additional training was, for divers having made at least one dive during the previous year, not found to be significantly associated with the likelihood of also reporting an ear injury (p=0.49), physical injury (p=0.84), panic (p=0.17), seasickness (p=0.09), an other diving injury (p=0.93) or any diving injury (p=0.45).

**Age and gender,** The mean age and percentage of divers who were male, stratified by injury type, is presented in table 9, for both injured and uninjured divers who had made at least one dive during the previous year.
Table 9

Mean age and percentage males by injury type

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>Injured</th>
<th></th>
<th></th>
<th>Not injured</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean age (years)</td>
<td>% Male</td>
<td>Mean age (years)</td>
<td>% Male</td>
<td></td>
</tr>
<tr>
<td>Ear injuries</td>
<td>30.4</td>
<td>66.7</td>
<td>32.5</td>
<td>75.4</td>
<td></td>
</tr>
<tr>
<td>Physical injuries</td>
<td>31.8</td>
<td>75.0</td>
<td>32.4</td>
<td>74.7</td>
<td></td>
</tr>
<tr>
<td>Panic</td>
<td>31.6</td>
<td>25.0</td>
<td>32.4</td>
<td>76.7</td>
<td></td>
</tr>
<tr>
<td>Seasickness</td>
<td>30.3</td>
<td>56.9</td>
<td>32.8</td>
<td>78.9</td>
<td></td>
</tr>
<tr>
<td>Other injuries</td>
<td>30.0</td>
<td>54.6</td>
<td>32.4</td>
<td>75.4</td>
<td></td>
</tr>
<tr>
<td>Any diving injury</td>
<td>30.7</td>
<td>61.7</td>
<td>33.1</td>
<td>80.5</td>
<td></td>
</tr>
</tbody>
</table>

Gender was not found to be significantly associated with the likelihood of reporting an ear injury (p=0.35), physical injury (p=0.98) or an other diving injury (p=0.12). Females were found to be significantly associated with an increased likelihood of reporting seasickness (p<0.01) and panic (p<0.01) suffered whilst diving during the twelve months prior to completing the questionnaire. Overall, females were more likely to report at least one diving injury of any type (p<0.01).

Age was not found to be significantly associated with the likelihood of reporting having suffered an ear injury (p=0.36), physical injury (p=0.85), panic (p=0.81), seasickness (p=0.11), an other diving injury (p=0.63) or an increased likelihood of reporting at least one diving injury of any type (p=0.07).

Minor Human Factors

Other human factors investigated, Smoking status, number of alcoholic drinks consumed each week, methods used to equalize the middle-ear spaces, pre-dive medication use, level of education, preferred angle of descent and the maximum number of ascents to the surface made during a single day within the twelve months prior to completing the questionnaire were also investigated for any relationship with diving injuries.
Of these minor potential risk factors the following associations were noteworthy:
Overall, drinking more alcohol (mean 9.4 drinks per week versus mean 7.2 drinks per week) was associated with fewer reports of at least one diving injury of any type (p=0.04). Females who reported ear injuries also reported drinking a mean of 3.5 drinks per week, whereas uninjured female divers reported drinking a mean 5.4 drinks per week (p=0.03).

Divers who equalize their ear spaces by yawning reported more cases of seasickness than divers using other methods (p=0.03). Females who equalize their ear spaces by contracting their jaw (n=28) reported significantly more ear injuries than female divers using other methods (p=0.02).

By counting the number of methods used to equalize the middle ear spaces during descent, an association was found between the number of methods females described using and the number of ear injuries reported (p=0.03). Female divers reporting ear injuries also reported using a mean of 2.3 methods (± 0.8) compared with 1.6 methods (± 0.7) used by uninjured female divers.

Reporting to have taken medication for decongestion within 12 hours of diving during the previous year was associated with an increased likelihood of reporting to have also suffered an ear injury (p=0.02). Naturally, there was a strong association between reporting having taken seasickness medication within 12 hours of diving and reporting having suffered seasickness (p<0.01). No female divers reported taking medication for blood pressure.

Forty-nine percent of divers reporting a diving injury of any type (n=46 out of 94) also reported taking at least one of the four listed medications within 12 hours of diving, compared with just 30% of uninjured divers (n=64 out of 210).

Divers were asked six questions indicative of risk taking, being whether they had, in the previous year, dived at night, inside a shipwreck, inside a cave, made a rapid ascent, runout of air or needed to share air with a buddy. The number of positive responses to these six questions was associated with an increased likelihood of also reporting either seasickness (p=0.04) or at least one diving injury of any type (p=0.01).
There was a significant positive trend ($p<0.01$) for reports of seasickness to increase with the reported highest level of education attained.

With the exception of those associations just described, there was no significant association between any of the five types of diving injury and the number of alcoholic drinks reportedly consumed each week, using any of the four individual methods of equalizing the middle ear spaces, or smoking status. There was no association between taking either anti-depressants or blood pressure medication and reporting to have had an episode of panic.

Males who reported having suffered an other injury during the previous year ($n=6$) also reported making a mean maximum of 4.0 ($\pm 1.3$) ascents in a single day of diving during the previous year. This was higher than reported by uninjured divers who made a mean maximum of 2.6 ($\pm 1.4$) ascents in a single day of diving ($p=0.02$).

There was no association between injury and preferred angle of descent, being headfirst, horizontal or feet-first, or between injury and whether divers usually/always or rarely/never logged their dives.

The significance of these human factors is summarised in table 10.
<table>
<thead>
<tr>
<th></th>
<th>Number of dives</th>
<th>Number of dives in last year</th>
<th>Number of dives per year</th>
<th>Time since certified</th>
<th>Additional training</th>
<th>Age</th>
<th>Gender</th>
<th>Education</th>
<th>Smoking status</th>
<th>Alcoholic drinks per week</th>
<th>Ascents per day</th>
<th>Methods of equalising</th>
<th>Medication</th>
<th>Risk taking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ear Injuries</td>
<td>+</td>
<td>♀</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>♀</td>
<td>X</td>
<td>♀</td>
<td>✅</td>
<td>X</td>
</tr>
<tr>
<td>Physical Injuries</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Panic</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>+</td>
<td>♀</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Sea Sickness</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>+</td>
<td>♀</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>♀</td>
<td>✅</td>
<td>X</td>
</tr>
<tr>
<td>Other Injuries</td>
<td>X</td>
<td>♀</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>+</td>
<td>X</td>
<td>X</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Any Injury</td>
<td>X</td>
<td>♀</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>+</td>
<td>♀</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>+</td>
<td>X</td>
</tr>
</tbody>
</table>

Note: ✅ = significance<0.05, ♀ = significance<0.05 for females only, ♂ = significance<0.05 for males only, X=significance>0.05

+ = direct relationship with prevalence of injury    - = inverse relationship with prevalence of injury
**Major Equipment Factors**

**Gear owned.** Almost all divers (n=296) owned a mask, snorkel and fins, with the next most commonly owned dive gear being a wetsuit and weightbelt (n=269). Two thirds of all divers reported owning the relatively more expensive BCD and regulators whilst less than 20% reported owning the least expensive item listed in the questionnaire, the safety sausage. Table 11 presents the distribution of gear ownership for active divers, and separately for injured and uninjured divers.

**Table 11**

*Ownership of individual items of dive gear*

<table>
<thead>
<tr>
<th>Dive Gear</th>
<th>Injured n (%)</th>
<th>Uninjured n (%)</th>
<th>Total n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mask/Snorkel/Fins</td>
<td>91 (96.8)</td>
<td>205 (97.6)</td>
<td>296 (97.4)</td>
</tr>
<tr>
<td>Wetsuit and Weights</td>
<td>81 (86.2)</td>
<td>188 (89.5)</td>
<td>269 (88.5)</td>
</tr>
<tr>
<td>BCD</td>
<td>68 (72.3)</td>
<td>141 (67.1)</td>
<td>209 (68.8)</td>
</tr>
<tr>
<td>Regulators and Gauges</td>
<td>66 (70.2)</td>
<td>136 (64.8)</td>
<td>202 (66.5)</td>
</tr>
<tr>
<td>Cylinder</td>
<td>57 (60.6)</td>
<td>122 (58.1)</td>
<td>179 (58.9)</td>
</tr>
<tr>
<td>Dive computer</td>
<td>41 (43.6)</td>
<td>81 (38.6)</td>
<td>122 (40.1)</td>
</tr>
<tr>
<td>Dive watch</td>
<td>24 (25.5)</td>
<td>71 (33.8)</td>
<td>95 (31.3)</td>
</tr>
<tr>
<td>Safety sausage</td>
<td>21 (22.3)</td>
<td>33 (15.7)</td>
<td>54 (17.8)</td>
</tr>
<tr>
<td>Owns no dive gear at all</td>
<td>3 (3.2)</td>
<td>3 (1.4)</td>
<td>6 (2.0)</td>
</tr>
</tbody>
</table>

When learning to dive, students are commonly required by dive schools to purchase a minimum of mask, snorkel and fins. Some dive schools require students to purchase a wetsuit. Table 12 presents the distribution of the number of items of dive gear owned. More than three-quarters of active divers (n=230) owned more than the minimum two items of dive gear commonly required to learn to dive.
Table 12
Total number of items of dive gear owned by injured status

<table>
<thead>
<tr>
<th>Number of items of dive gear</th>
<th>Injured n (%)</th>
<th>Uninjured n (%)</th>
<th>Total n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3 (3.2)</td>
<td>3 (1.4)</td>
<td>6 (2.0)</td>
</tr>
<tr>
<td>1</td>
<td>8 (8.5)</td>
<td>18 (8.6)</td>
<td>26 (8.6)</td>
</tr>
<tr>
<td>2</td>
<td>9 (9.6)</td>
<td>32 (15.2)</td>
<td>41 (13.5)</td>
</tr>
<tr>
<td>3</td>
<td>5 (5.3)</td>
<td>15 (7.1)</td>
<td>19 (6.7)</td>
</tr>
<tr>
<td>4</td>
<td>7 (8.8)</td>
<td>10 (5.1)</td>
<td>20 (6.6)</td>
</tr>
<tr>
<td>5</td>
<td>15 (16.0)</td>
<td>35 (16.7)</td>
<td>50 (16.5)</td>
</tr>
<tr>
<td>6</td>
<td>29 (30.9)</td>
<td>54 (25.7)</td>
<td>83 (27.3)</td>
</tr>
<tr>
<td>7</td>
<td>5 (5.3)</td>
<td>29 (13.8)</td>
<td>34 (11.2)</td>
</tr>
<tr>
<td>8</td>
<td>11 (11.7)</td>
<td>13 (6.2)</td>
<td>24 (7.9)</td>
</tr>
</tbody>
</table>

Overall, gear ownership was not found to be significantly associated with the likelihood of reporting having suffered an ear injury (p=0.27), a physical injury (p=0.09), panic (p=0.93), seasickness (p=0.16), an other injury (p=0.06) or at least one diving injury of any type (p=0.45).

Alternate air source use, Divers were asked if they dived with an alternate air source, and were categorised as either usually-always diving with an alternate air source (n=203), or rarely-never diving with one (n=101). Divers reporting to have run out of air and made for the surface during the twelve months prior to completing the questionnaire (n=20) were significantly more likely to also report rarely or never carry an alternate air source whilst diving (p<0.01). Despite this, diving with an alternate air source was not found to be significantly associated with the likelihood of reporting an ear injury (p=0.36), physical injury (p=0.14), panic (p=0.54), seasickness (p=0.19), an other injury (p=0.13) or at least one diving injury of any type (p=0.95) during the twelve months prior to completing the questionnaire.

Uncontrolled ascents in last year, Twenty-eight divers (9.2%) reported having made an uncontrolled ascent to the surface during the previous year. Reporting to have made an uncontrolled ascent whilst diving during the previous year was not significantly associated with the likelihood of reporting a physical injury (p=0.64), seasickness
(p=0.40), an other diving injury (p=0.99) or at least one diving injury of any type (p=0.15), but was associated with reporting an ear injury (p=0.04) and panic (p=0.05).

Compared to divers who are assumed to have only made controlled ascents, divers reporting to have made an uncontrolled ascent to the surface during the twelve months prior to completing the questionnaire (n=28) were neither more, nor less, likely to report owning a BCD (p=0.75).

**Minor Equipment Factors**

*Other equipment factors investigated,* Ownership of individual items of dive gear, ownership of a diving textbook, use of a dive computer, use and ownership of a safety sausage, having shared air or run out of air within the last year, ownership of a boat and left or right handedness was also tested for association with the likelihood of reporting each type of injury.

Of these minor potential risk factors the following associations were noteworthy: Reporting to have run out of air and made for the surface during the previous year was associated with also reporting to have suffered a physical injury whilst diving (p<0.01). Whether the injuries were a result of the ascents remains unknown.

There was no significant association between any of the five types of injury and ownership of either a BCD or a dive computer. Ownership of a boat was not significantly associated with injury, not even with seasickness (p=0.10), nor was having shared air with a buddy whilst diving during the previous year nor, despite the inability of some dive gear to be worn on either side, whether the divers were left-handed, right-handed or ambidextrous. Claiming to always/usually or rarely/never plan dives using dive tables had no association with reporting any of the five types of injuries.

The significance of each equipment factor is summarised in table 13.
Table 13
Significance of equipment risk factors for diving injuries – Summary table.

<table>
<thead>
<tr>
<th></th>
<th>Gear Ownership</th>
<th>Carry Air Source</th>
<th>Uncontrolled Ascent</th>
<th>Own a Diving Textbook</th>
<th>Run Out of Air</th>
<th>Ownership of a BCD</th>
<th>Use a Dive Computer</th>
<th>Shared Air</th>
<th>Left or Right Handed</th>
<th>Use Dive Tables</th>
<th>Own a Safety Sausage</th>
<th>Ownership of a Boat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ear Injuries</td>
<td>X</td>
<td>X</td>
<td>+</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Physical Injuries</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>+</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Panic</td>
<td>X</td>
<td>X</td>
<td>+</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Sea Sickness</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>+</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Other Injuries</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Any Injuries</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Note: ✔ = significance<0.05, ♂= significance<0.05 for females only, ♂= significance<0.05 for males only, X=significance>0.05
+ = direct relationship with prevalence of injury  - = inverse relationship with prevalence of injury
**Major Societal/Environmental Factors**

**Solo diving,** Sixteen divers (5.3%) who made dives during the previous year claimed to rarely or never dive with a buddy, and diving alone was significantly associated with having run out of air and made for the surface (p=0.04). Despite this, diving unaccompanied during the previous year was not significantly associated with the likelihood of reporting an ear injury (p=0.23), physical injury (p=0.86), panic (p=0.40), seasickness (p=0.49), an other diving injury (p=0.43) or at least one diving injury of any type (p=0.28).

**Deepest recent dive,** The mean maximum depth reached during the previous year by divers making at least one dive, stratified by injury type, is presented in table 14, for both injured and uninjured divers.

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>Mean maximum depth reached in previous year (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Injured</td>
</tr>
<tr>
<td>Ear injuries</td>
<td>28.3 ± 11.3</td>
</tr>
<tr>
<td>Physical injuries</td>
<td>24.7 ± 6.9</td>
</tr>
<tr>
<td>Panic</td>
<td>23.3 ± 9.1</td>
</tr>
<tr>
<td>Seasickness</td>
<td>26.2 ± 9.8</td>
</tr>
<tr>
<td>Other injuries</td>
<td>26.4 ± 9.7</td>
</tr>
<tr>
<td>Any dive injuries</td>
<td>25.5 ± 9.6</td>
</tr>
</tbody>
</table>

The deepest dive reported to have been made during the previous year was not found to have a relationship with the likelihood of reporting a physical injury (p=0.49), panic (p=0.99) or an other diving injury (p=0.22), but was found to be significantly associated with an increased likelihood of reporting an ear injury (p=0.03), seasickness (p<0.01) or any diving injury (p<0.01).

Entry-level dive courses train divers to safely reach a maximum depth of 18m, equivalent to a maximum of one minute’s travel from the surface if ascending at the maximum recommended ascent rate of 18m/min.
Dividing the maximum depths reached during the previous year into 18m or less, or more than 18m, then having dived to more than 18m was not significantly associated any of the five types of diving injury.

**Motivation for diving,** Divers were asked for reasons why they made dives during the previous year. Males were more likely than females to report having hunted for crayfish (OR 3.18, 95% CI 1.86, 5.42), hunted for abalone (OR 1.39, 95% CI 0.50, 3.84) and/or to have gone spearfishing (OR 29.20, 95% CI 3.97, 214.45), and less likely than females to report having gone diving to take photos (OR 0.42, 95% CI 0.24, 0.72) and/or to have gone in search of a specific animal such as a sea-dragon (OR 0.43, 95% CI 0.23, 0.82).

Diver trainers, during the construction of the questionnaire, commonly predicted that hunters would report having suffered more ear injuries than non-hunters, citing the need to carry catch-bags, spear guns and/or cray-snares as the reason for this prediction. With at least one hand carrying hunting equipment the diver has to equalise the middle ear spaces and manually inflate and deflate the BCD using the one remaining hand instead of using one hand for each task.

Hunting for crayfish was not found to be significantly associated with the likelihood of reporting an ear injury (p=0.06), physical injury (p=0.46), panic (p=0.19), an other diving injury (p=0.71) or at least one diving injury of any type (p=0.18) but was found to be significantly associated with an increased likelihood of reporting seasickness (p=0.02).

Hunting for abalone was not found to be significantly associated with the likelihood of reporting an ear injury (p=0.43), physical injury (p=0.52), panic (p=0.99), seasickness (p=0.24) or an other diving injury (p=0.92) or at least one diving injury of any type (p=0.31).

Spearfishing was not found to be significantly associated with the likelihood of reporting an ear injury (p=0.58), physical injury (p=0.10), panic (p=0.27), seasickness (p=0.43), an other diving injury (p=0.32) or at least one diving injury of any type (p=0.59).
Females who engaged in hunting (n=38) were, however, more likely to report having suffered panic whilst diving during the previous year (p=0.01).

Forty-eight percent of divers (n=146) reported having been motivated to go diving during the previous year to visit a shipwreck, and this was not significantly associated with any reporting an ear injury (p=0.14), physical injury (p=0.23), panic (p=0.65) or an other injury (p=0.09). Divers who reported having been motivated to dive during the previous year by the prospect of visiting a shipwreck were significantly more likely to also report having suffered seasickness during the previous year (p=0.02), and at least one injury of any type (p<0.01).

Taking photographs underwater not only requires the dedicated use of at least one hand but also distracts the diver from such tasks as monitoring changes in depth and how much air remains within the dive cylinder. Despite this, reporting to have been diving to take photographs during the previous year was not significantly associated with also having reported ear injuries (p=0.47), physical injuries (p=0.10), panic (p=0.28), seasickness (p=0.11), an other injury (p=0.79) or at least one injury of any type (p=0.43).

Of the divers reporting to have been motivated to dive in search of a specific animal such as a sea-dragon (n=50), and with the exception of males who were significantly more likely to also report having suffered at least one injury of any type (p=0.02), there were no other significant associations between diving in search of a particular animal and reporting ear injuries (p=0.08), physical injuries (p=0.80), panic (p=0.98), seasickness (p=0.80) or an other injury (p=0.50).

**Safety stops,** Divers were asked if they made safety stops at the end of their dives, and were classified as rarely-never or usually-always. Reporting to rarely or never make safety stops whilst diving was not significantly associated with the likelihood of reporting an ear injury (p=0.92), physical injury (p=0.41), panic (p=0.10), seasickness (p=0.42), an other diving injury (p=0.95) or at least one diving injury of any type (p=0.84).
**Minor Societal/Environmental Factors**

*Other societal/environmental factors investigated,* Other factors tested for significant associations with the five types of injury were the number of dives made outside of WA, the number of dives made from charter-boats, having dived inside a cave, inside a shipwreck or at night, and how many of each diver’s immediate family also dive.

Of these *minor* potential risk factors the following associations were noteworthy: Those divers having reported to have dived inside a cave were also more likely to report having suffered an other injury ($p=0.03$). Divers reporting to have dived inside shipwreck were also more likely to report having suffered at least one diving injury of any type ($p<0.01$). Having made at least one dive from a charter boat within the previous year was associated with increased likelihood of reporting seasickness ($p=0.01$), an other injury ($p=0.03$) or at least one injury of any type ($p=0.02$). Having made at least one dive outside of WA within the previous year was associated with increased likelihood of reporting an other injury ($p<0.01$).

Other than those presented above, there was no association between any of the five types of injury and having dived at night, nor with the number of dives reportedly made outside of WA, nor whether or not any immediate family also dive.

The significance of these societal/environmental factors is summarised in table 15.
Table 15
Significance of societal/environment risk factors for diving injuries – Summary table.

<table>
<thead>
<tr>
<th></th>
<th>Solo Diving</th>
<th>Deepest Dive</th>
<th>Dived &gt;18m</th>
<th>Dived to go Hunting</th>
<th>Visited a Shipwreck</th>
<th>Dived to Take Photographs</th>
<th>Dived Inside a Shipwreck</th>
<th>Dived to Take Photographs</th>
<th>Dived Inside a Cave</th>
<th>Dived From a Charter Boat</th>
<th>Dived at Night</th>
<th>Dived Outside of WA</th>
<th>Immediate Family Also Dive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ear Injuries</td>
<td>X</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Injuries</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panic</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sea Sickness</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Injuries</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any Injuries</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: ✓ = significance<0.05, ♂ = significance<0.05 for females only, ♀ = significance<0.05 for males only, X=significance>0.05
+
= direct relationship with prevalence of injury
- = inverse relationship with prevalence of injury
**Significant Risk Factors**

Logistic regression using a general linear model was conducted with backward variable elimination set at a significance level of 0.05 or less for variables and/or interactions. This procedure was conducted separately for each type of injury and followed by an overall model including all risk factors and all dive injuries.

The linear regression model takes the general form:

\[ \ln \left( \frac{p}{1-p} \right) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k \]

where \( p \) = the proportion of the sample with the injury, \( \alpha \) = the intercept, \( k \) = the number of variables, \( x_k \) = the independent variables and \( \beta_k \) = the coefficients for each variable.

As it would not make sense to fit both the total number of medications taken and the individual medications to the same model, an *a priori* decision was made to fit the total number of medications taken within the logistic model. The same decision was made with regard to the total number of methods reportedly used to equalise the middle ear spaces during descent, as opposed to fitting the individual methods. Likewise, entry-level divers are trained to reach a maximum depth of 18m and an *a priori* decision was made to classify the maximum depth reached during the previous year as either 18m or less, or greater than 18m, rather than fit the actual depths reported to the model.

*For ear injuries*, Table 16 presents the odds ratios and confidence intervals for the remaining risk factors for reporting having suffered at least one ear injury whilst diving during the previous year.

**Table 16**

<table>
<thead>
<tr>
<th>Risk Factors</th>
<th>Odds Ratio</th>
<th>95% Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Having made an uncontrolled ascent</td>
<td>3.25</td>
<td>1.09, 9.62</td>
</tr>
<tr>
<td>Number of equalising methods</td>
<td>1.60</td>
<td>1.00, 2.56</td>
</tr>
</tbody>
</table>
For physical injuries, Table 17 presents the odds ratios and confidence intervals for the remaining risk factors for reporting having suffered at least one physical injury whilst diving during the previous year.

Table 17
Odds ratios and confidence intervals for risk factors associated with physical injury

<table>
<thead>
<tr>
<th>Risk Factors</th>
<th>Odds Ratio</th>
<th>95% Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Running out of air Vs not running out</td>
<td>9.80</td>
<td>2.75, 34.48</td>
</tr>
<tr>
<td>Having dived deeper than 18m</td>
<td>4.83</td>
<td>1.21, 19.23</td>
</tr>
<tr>
<td>Owning a boat Vs not owning a boat</td>
<td>3.05</td>
<td>1.01, 9.17</td>
</tr>
</tbody>
</table>

For panic, Table 18 presents the odds ratios and confidence intervals for the remaining risk factors for reporting having experienced panic whilst diving during the previous year.

Table 18
Odds ratios and confidence intervals for risk factors associated with panic

<table>
<thead>
<tr>
<th>Risk Factors</th>
<th>Odds Ratio</th>
<th>95% Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (female Vs male)</td>
<td>9.88</td>
<td>2.60, 37.5</td>
</tr>
</tbody>
</table>

For seasickness, Table 19 presents the odds ratios and confidence intervals for the remaining risk factors for reporting having suffered seasickness whilst diving during the previous year.
Table 19

Odds ratios and confidence intervals for risk factors associated with seasickness

<table>
<thead>
<tr>
<th>Risk Factors</th>
<th>Odds Ratio</th>
<th>95% Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use computer to plan dives Vs not</td>
<td>2.15</td>
<td>1.07, 4.31</td>
</tr>
<tr>
<td>Having dived inside a wreck Vs not</td>
<td>1.93</td>
<td>1.04, 3.60</td>
</tr>
<tr>
<td>Number of medications taken</td>
<td>2.24</td>
<td>1.51, 3.33</td>
</tr>
<tr>
<td>Gender (female Vs male)</td>
<td>2.53</td>
<td>1.33, 4.78</td>
</tr>
</tbody>
</table>

For other injuries, Table 20 presents the odds ratios and confidence intervals for the remaining risk factors for reporting at least one other injury, suffered whilst diving during the previous year.

Table 20

Odds ratios and confidence intervals for risk factors associated with other injuries

<table>
<thead>
<tr>
<th>Risk Factors</th>
<th>Odds Ratio</th>
<th>95% Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diving with an alternate air source Vs not</td>
<td>0.22</td>
<td>0.05, 0.90</td>
</tr>
<tr>
<td>Number of dives made during last year</td>
<td>2.45</td>
<td>1.21, 4.99</td>
</tr>
<tr>
<td>Gender (female Vs male)</td>
<td>5.14</td>
<td>1.26, 20.94</td>
</tr>
</tbody>
</table>

For at least one diving injury of any type, Overall, divers having made at least one dive during the previous year and who were female were two and a half times more likely than males to report having suffered at least one diving injury whilst diving during the previous year. For each of the four listed types of medication taken the risk of reporting an injury increased nearly twofold. Table 21 presents the odds ratios and confidence intervals for the remaining risk factors for reporting having suffered at least one diving injury of any type during the previous year.
Table 21

Odds ratios and confidence intervals for risk factors associated with at least one diving injury of any type

<table>
<thead>
<tr>
<th>Risk Factors</th>
<th>Odds Ratio</th>
<th>95% Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of medications taken</td>
<td>1.79</td>
<td>1.25, 2.57</td>
</tr>
<tr>
<td>Gender (female Vs male)</td>
<td>2.55</td>
<td>1.45, 4.49</td>
</tr>
</tbody>
</table>

**Conclusion**

Whilst the number of dives made was associated with reporting a diving injury classed as type “other”, in this study diving experience, measured by the number of dives made during the previous year and the total number of dives made since certification, has not been found to be associated with the likelihood of reporting having suffered at least one diving injury of any type whilst diving during the previous year.
Chapter 5
Discussion and conclusions

Overview
Chapter 2 presented an overview of the potential injuries and risk factors likely to be found amongst Western Australian recreational divers, and the risk factors were classed as either human factors, equipment factors or environmental factors. Likewise, chapter 4 examined the prevalence of individual injuries, each type of injury, and then the prevalence of each risk factor according to type. This chapter discusses the findings by firstly examining the potential for bias before comparing the findings with those of other studies, with the prevalence of individual injuries considered firstly, followed by the prevalence of potential risk factors, grouped into human, equipment and environmental factors. The chapter then closes with a look at the relevance of these findings.

Objectives
At the conclusion of chapter 2 the objectives of this research were stated as:

• Measure the prevalence of a history of diving-related injuries amongst West Australians with varying levels of experience since certification as entry-level divers within WA.
• Identify potential risk factors associated with diving related injuries amongst Western Australian divers, such as equipment ownership, diving behavior, gender and medication use.

Factors Relating to Validity
Threats to the validity of cross sectional studies are many, varied and include potential sources of bias, the most common of which are now discussed.

Selection bias, whereby respondents differ to non-responders (102), poses a serious potential bias to the present study. During the 1999 study of Western Australian recreational divers (50) researchers were supplied with contact details for each diver and, thus, were able to conduct an abbreviated non-responder survey to determine the extent of any differences between responders and non-responders, (no difference was found). The limiting factor in the case of the present study was the requirement for
anonymity due to the commercial sensitivity of each dive school’s customer list. Accordingly, non-responders remained anonymous and were not contacted again at a later date, so it has not been possible to determine if respondents consistently differ to non-responders. With just a 25% response rate, selection bias has the potential to threaten the validity of the findings. Given the limitations of the study it was not possible to contact the non-responders, nor to advertise state-wide for non-responders to take part in the survey, nor to offer incentives to increase the response rate. Though 2077 questionnaires were delivered to dive centres within WA, it remains unknown how many actually reached the divers they were intended for.

Two long established dive centres did, however, supply dates of birth and dates of certification for every entry-level diver certified at those dive centres since 1999 (n=349). The mean ages and gender proportions are presented in table 22.

Table 22
Gender and age distributions for two dive centres and survey respondents

<table>
<thead>
<tr>
<th></th>
<th>Two dive centres</th>
<th>Respondents</th>
<th>Two dive centres - age at certification (years)</th>
<th>Respondents age at certification (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>246 (71%)</td>
<td>227 (75%)</td>
<td>29.8 (± 11.7)</td>
<td>32.9 (± 10.9)</td>
</tr>
<tr>
<td>Females</td>
<td>101 (29%)</td>
<td>77 (25%)</td>
<td>29.5 (± 10.4)</td>
<td>30.7 (± 10.6)</td>
</tr>
<tr>
<td>Total</td>
<td>349 (100%)</td>
<td>304 (100%)</td>
<td>29.7 (± 11.3)</td>
<td>32.4 (± 10.8)</td>
</tr>
</tbody>
</table>

There were no significant differences between the 349 training records and the 304 respondents in either mean age at certification (p=0.24) or gender distributions (p=0.34). This suggests the respondents do not significantly differ in either age or gender to the complete sample of training records drawn from two participating dive schools. Though it cannot be stated with certainty that the two dive centres supplying these details do not differ in any significant way from the other diver training facilities within WA, visits made to each dive centre failed to find any reason why these two dive centres might have different customer bases to the other Western Australian dive schools. Accordingly, it would appear that respondents to the survey do not appear different in gender and age to a sample drawn from two participating dive centres, and that sample is unlikely to differ from the population of divers trained within WA during
the last six years. A comparison of ages and gender proportions between the respondents to this survey and other populations of recreational divers is attached as appendix four and, likewise, suggests the respondents to this survey are similar to other populations of recreational divers with regard to these two factors. Even so, with a response rate of just 25%, caution must be exercised before extrapolating the findings of this research to the wider, trained diving population within WA.

Misclassification bias, where the information supplied is inadequate for ensuring accurate classification (102), is another potential source of bias associated with cross sectional studies. In the present study the questionnaire did not define panic and so the misclassification of one gender as either having suffered panic or not, resulting in a bias, may have occurred, especially as injury history was self-classified and without follow-up. Only further and more detailed research will uncover the extent of any injury misclassification and, if the misclassification is consistent, in which direction it exists (either excluding injured divers or including non-injured divers).

Instrument bias occurs when the wording of questions predisposes participants to certain answers (103), by attaching either a positive or negative association to the question, and in the present study the potential for this bias to affect the results was minimised by using a reference group to assess the face and content validity of the instrument.

Recall bias occurs when there is a difference between groups regarding the likelihood they will recall events (102), for example when injured divers recall the events surrounding a dive with more clarity than divers who did not suffer an injury. In this case, the questionnaire did not investigate individual injuries. Rather, the survey collected broad information particular to the year prior to completing the questionnaire. Though divers may have difficulty remembering details such as the number of dives made, whether or not a diver has suffered a diving injury should not consistently affect the ability to remember such information, meaning the ability to recall broad information would not be greater amongst either injured or uninjured divers.

Membership bias occurs when members of a population that have a particular trait, such as having suffered a diving injury, are more or less likely to respond than the members
of the population without such a trait. That divers, who have suffered an injury, feel a sense of shame or guilt has been shown (104). Though the present study was conducted anonymously, it is possible that injured divers may have been less willing to participate, or it may have been that injured divers were more willing to participate, having had an injury to report. Either way, with just response rate of just 25% it is possible for a degree of membership bias to have affected the results.

In summary, of the main types of bias associated with cross sectional studies, selection bias, information bias and membership bias have the greatest potential to threaten the validity of the findings of this study. The degree to which any of these has affected the present study cannot be known with certainty, so caution should be exercised when interpreting the results.

Results

Injury prevalence, Overall, 30% of divers reported suffering some form of diving injury during the previous year. Seasickness was the most common diving injury, with 19% reporting to have suffered it whilst diving during the previous year. This bears similarity to the axiom that one in five divers always gets seasick, one in five never gets seasick, and the remaining three only get sick in extreme conditions.

Similar injury classifications to those used in the present study could not be found used elsewhere, thus it has not been possible to compare the reported number of injuries of each type directly with the number reported by other diving populations.

Of the ear injuries reported, vertigo was the most common at 4.3% (n=13) of divers. This is lower than found amongst 64 dive club members in Germany (27%) though that study investigated injuries that occurred during the entire diving career of participants (19). Compared with the survey of Australian dive club members (7), this study has found fewer cases of ruptured ear drum (0.7% Vs 6.1%), though again the former study assessed a past history of injury beyond one previous year. Probably for the same reason, tinnitus has been found, in this study, to have a lower prevalence (1.3% Vs 12.1%), as has hearing loss (3.0% Vs 3.8%). Regardless, ear injuries appear to have affected one in twelve divers during the previous year, and these were associated with
poor buoyancy control and difficulty equalising, despite these skills featuring heavily during entry-level training. Ownership of a BCD was not found associated with having fewer ear injuries.

Describing the temporal relationship between incidence of vertigo, tinnitus and hearing loss falls beyond the limitations of this study.

Physical injuries suffered whilst diving affected 5% of divers during the previous year, including 1% (n=3) who reported suffering DCS. Amongst other recreational diving populations, the number of cases of decompression sickness per 10,000 recreational dives has been reported as 1.0 (105), 1.1 (48), 3.4 (36), 5.9 (41) and 8.4 (62). Within WA this research found three cases reported for 5550 dives, equating to 5.4 cases per 10,000 dives. Risk factors for physical injuries included running out of air, which is often associated with a rapid ascent, and having dived deeper than 18m during the previous year. Boat ownership was also associated with reporting a physical injury, and it is likely that divers who own boats are more able to access deeper water.

Panic has been found to have occurred whilst diving in 27% (n=3278) of divers responding to an American on-line survey (32). In that study the distribution of cases between genders was reported as 24% (n=2205) amongst males and 37% (n=1073) amongst females. In the present study females have been found significantly more likely than males to report having suffered panic whilst diving during the previous year. Why this might be so is deserving of further research.

There is no clear explanation why gender, education, dive computer use and/or wreck penetration should be associated with seasickness.

Eleven divers (3.6%) reported an other injury, four of those tooth squeeze and eight described their injuries in free format. These descriptions included vomiting after drinking heavily the night before, occasional ear infections, a “stretched ear drum”, bad leg cramps, a twisted knee, headache (2), and a broken nail. That reporting an other injury was associated with diving without an alternate air source cannot be easily explained. Reporting to have suffered an other injury was, however, positively associated with the number of dives made, so the more dives a diver made then the
more likely they might suffer an injury of some general type, and females were five times more likely to report having suffered such an injury.

Tooth squeeze has been reported as occurring once per 10,000 dives (6), yet in the present study four cases were reported to have occurred whilst diving during the year prior to completing the survey, during which 5,550 dives were reported, equating to seven cases per 10,000 dives. Once again it must be remembered that the response rate was just 25%, and that divers who had suffered this rare injury might be more likely to participate than divers who had not suffered any injury during the previous year. Whether or not this was the case remains unknown.

Overall, reporting at least one injury of any type was associated with the number of medications taken within 12 hours of diving, and with gender. The strength of association between injury and the number of medications taken was probably influenced by the taking of seasickness medication and reporting seasickness, though decongestant medication use was also associated with ear injury during the univariate analysis. It stands to reason that divers who do not require seasickness medication to travel by sea, and divers who do not require decongestant medication to facilitate equalising the middle ear space, are at less risk of reporting having suffered a diving injury.

That females are, overall, 2.6 times more likely than males to report having suffered at least one diving injury of any type during the previous year remains unexplained, and further research is warranted, ideally a prospective study. That the risk of females reporting an ear injury decreased as the number of dives they had made increased (p=0.02) suggests the possibility that females find equalising easier with experience.

**Human factors,** The mean number of dives made by respondents was 18.3 which appears to be less than the mean number of dives made per year by other recreational diving populations, for example 39 dives per year by Australian dive club members (7), 25 dives per year by British asthmatic divers (106) and more than 28 dives per year by Swiss dive club members (107). Though elsewhere the measure of central tendency reported has been the mean number of dives, with a large standard deviation typical of
right-skewed distributions, the mean was not thought the most appropriate measure in the present study.

That 33.8% of respondents had completed a dive course beyond entry-level is in keeping with the study of 285 active divers in Queensland in 1989 (43), which found 33% had completed at least one additional dive course. That the present study found only 16.7% of participants who reported having suffered panic whilst diving during the previous year had completed additional training is unexpected, though more research is needed to uncover the nature of any association between continuing education and panic.

Scuba is a physical pursuit that requires access to resources such as transport, equipment and money for air, trips, repairs etc. That the mean age of the sample, when certified, was 32.9 years for males and 30.7 years for females is reassuringly similar to the mean ages of other recreational diving populations, as described more fully in appendix four. With a 25% response rate though, it is possible that the mean age is more representative of those divers willing to participate than of the trained diver population at large.

That the number of medications taken within 12 hours of diving appears associated with reporting either seasickness or at least one injury of any type may well be as a result of the close association between taking seasickness medication and suffering seasickness.

The univariate analysis found that taking decongestant medication was associated with reporting an ear injury. One possible explanation is that divers who have trouble equalising and who feel the need to take this medication are at increased risk, yet equally it may be that divers who have suffered an ear injury subsequently take decongestant medication as a precaution. As temporality was not investigated by this study, the exact nature of this association remains unknown, though the likelihood of reporting an ear injury increased by a factor of 1.6 for each additional method reportedly used for equalizing the middle ear space, suggesting that divers with problems equalizing are more likely to suffer an ear injury.
That increased alcohol consumption was found associated with a decreased likelihood of reporting at least one diving injury of any type was an unexpected, counterintuitive finding, and should be interpreted cautiously, not least because the research design does not investigate temporality, and thus the relevance of drinking, for example, four drinks fours days before a dive is questionable at best. Given the close association between alcohol and many other forms of injury, more detailed research into the relationship between alcohol consumption and diving injury is needed before this finding can be placed into context.

**Equipment factors,** Gear ownership was not associated with diving injury, though having made an uncontrolled ascent to the surface during the previous year was associated with reporting an ear injury, suggesting poor buoyancy control, coupled with difficulty equalizing, may have a stronger association with ear injury than mere ownership of a BCD.

Ownership of an alternate air source, whilst associated with the likelihood of reporting an other injury, was strongly associated with having run out of air and made for the surface. One third of all recently trained divers made dives during the previous year whilst rarely or never carrying an alternate air source, even though during training the need to carry an alternate air source and the ability to use one is stressed in training videos, DVDs, textbooks, features in written tests, is taught in the pool on numerous occasions and tested in the open water (108). Despite the obvious danger associated with running out of air, and the association between running out of air and reporting a physical injury, ownership of an alternate air source was not found to reduce to likelihood of reporting an injury. It would appear that, regardless of whether a diver carries an alternate air source or not, divers that run out of air are at increased risk of injury. The questionnaire did not define *Alternate Air Source,* and how this affected the data is unknown.

Many Western Australian charter boat operators are already requiring passengers to carry a safety sausage, and this may explain why there was an association between safety sausage ownership and the likelihood of reporting seasickness (p=0.03).
Environmental factors, That the sixteen divers who rarely or never dived with a buddy during the previous year were also more likely to have run out of air (p=0.04) is cause for alarm, especially when running out of air was significantly associated with reporting a physical injury. Diving alone is a clear breach of accepted safe practices (109).

Having dived deeper than 18m was associated with reporting having suffered a physical injury during the previous year. Further research is required to uncover the exact nature of this association.

Underwater hunting in Western Australia, as expected, was a typically male pastime, though surprisingly not associated with any reported diving injuries other than seasickness, except for female hunters who were more likely to also report panic. Once again the low response rate must be borne in mind, as injured hunters may have excluded themselves, thus introducing a selection bias. Whether or not this occurred remains unknown.

Diving inside a shipwreck requires a wreck of considerable size, and within WA few such wrecks, if any, are reachable by swimming from the shore. This fact probably accounts for the association between having dived inside a shipwreck during the previous year and reporting to have suffered seasickness.

Conclusion
The thesis is that diving experience is associated with the likelihood of reporting a dive injury and this research has found a relationship between the number of dives made during the previous year and reporting to have suffered an other injury, whereby the 11 divers reporting to have suffered an other injury made a median of 20.0 dives compared with a median of 12.0 dives for uninjured divers (p<0.05). Even so, the sample of injured divers having suffered other injuries remained small and, in this study, the overall likelihood of reporting a diving injury of any type was not found to be associated with diving experience, measured as either the number of lifetime dives or by the number of dives made during the previous year.
Various risk factors have been found to be associated with different types of injury, and these appear plausible associations, such as in the case of implied difficulty equalizing and reporting an ear injury. Of these various risk factors, those deserving of closer scrutiny include the relationship between females and panic, seasickness and at least one injury of any type, and the relationship between diving deeper than 18m and suffering a physical injury.

Interestingly, many of the factors thought likely to be associated with diving injury and, as such, described as major factors, were not found in this study to be significantly associated with diving injury. Conversely, many minor factors were found to be significantly associated with reporting to have suffered a diving injury during the previous year. These findings will assist the design of future research into risk factors for injury amongst Western Australian divers, and/or the design of diving safety interventions.

These findings also suggest the information that might be of most use to Western Australian divers includes methods of equalisation, strategies for minimising and coping with panic and seasickness, the importance of buoyancy control, how to avoid running out of air and the potential hazards associated with diving deeper than 18m.
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Appendix 1: Literature Search

A search of the UWA library catalogue failed to identify a study of diving injury prevalence amongst Western Australian recreational divers. Using the search terms “scuba”, “diving” and/or “decompression”, electronic database searches were made of Medline, Proquest, the ABS catalogue of publications, SPORTDiscuss, Biological Abstracts, Embase, Digital Thesis Repository, AustHealth, Ovid Journals, MLA International Bibliography, PsychINFO, ERIC, AUSPORT, Factiva, AGRICOLA, CAB Abstracts, CINAHL (Cumulative Index to Nursing and Allied Health Literature), Global Health, Zoological Record, Timebase and Austlii, up to and including May 2005. The electronic archives of the British Medical Journal, International Journal of Epidemiology, Aviation Space and Environmental Medicine, Wilderness and Environmental Medicine, Chest, Neurology, Stroke, Journal of Applied Physiology, Heart, Headache, the Divers Alert Network, National Sea Grant Program and the journal of the Undersea and Hyperbaric Medicine Society were each searched.

Publications identified as related to diving injuries were obtained and the bibliography of each searched for further related publications. Diving medicine texts recently listed by the South Pacific Underwater Medicine Society (SPUMS) as resources for the epidemiology of Australian diving accidents were obtained (97).
Appendix 2: Information Letter
Appendix 3: Western Australian Diver Survey
Appendix 4: Comparison with other diver studies

Table 23 compares the overall mean age and proportion of respondents that are male against other surveys of divers.

Table 23
Comparison between respondents and other diving populations

<table>
<thead>
<tr>
<th>Diver Population</th>
<th>Locale</th>
<th>Response Rate %</th>
<th>n</th>
<th>Mean Age (years)</th>
<th>Proportion Male %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dive resort visitors</td>
<td>Japan (22)</td>
<td>na</td>
<td>3819</td>
<td>31.4</td>
<td>62</td>
</tr>
<tr>
<td>Divemasters/Instructors</td>
<td>Sweden (8)</td>
<td>73</td>
<td>1742</td>
<td>32</td>
<td>87</td>
</tr>
<tr>
<td>Injured divers</td>
<td>Hawaii (26)</td>
<td>na</td>
<td>1192</td>
<td>34.4</td>
<td>~75</td>
</tr>
<tr>
<td>Charter boat divers</td>
<td>Texas (55)</td>
<td>56</td>
<td>528</td>
<td>39</td>
<td>75</td>
</tr>
<tr>
<td>Trained divers</td>
<td>WA (50)</td>
<td>55</td>
<td>515</td>
<td>27</td>
<td>72</td>
</tr>
<tr>
<td>This study</td>
<td>WA</td>
<td>25</td>
<td>499</td>
<td>30.7</td>
<td>73</td>
</tr>
<tr>
<td>Dive resort visitors</td>
<td>Mede Is. (44)</td>
<td>na</td>
<td>500</td>
<td>31-45</td>
<td>80</td>
</tr>
<tr>
<td>Trained divers</td>
<td>Michigan (46)</td>
<td>51</td>
<td>386</td>
<td>21-30</td>
<td>86</td>
</tr>
<tr>
<td>Trained active divers</td>
<td>Queensland (43)</td>
<td>30</td>
<td>380</td>
<td>28</td>
<td>61</td>
</tr>
<tr>
<td>Dive club members</td>
<td>Australia (6)</td>
<td>na</td>
<td>346</td>
<td>31-40</td>
<td>61</td>
</tr>
<tr>
<td>First-time divers</td>
<td>Queensland (34)</td>
<td>37</td>
<td>294</td>
<td>29.2</td>
<td>73</td>
</tr>
<tr>
<td>Charter boat divers</td>
<td>Florida (110)</td>
<td>na</td>
<td>223</td>
<td>15-36</td>
<td>62</td>
</tr>
<tr>
<td>Dive club members</td>
<td>Geneva (107)</td>
<td>na</td>
<td>215</td>
<td>35.7</td>
<td>67</td>
</tr>
<tr>
<td>Dive club members</td>
<td>Germany (111)</td>
<td>na</td>
<td>87</td>
<td>35.7</td>
<td>77</td>
</tr>
</tbody>
</table>

Despite the lower response rate, the respondents in this study have a mean age and proportion who are male which are consistent with those found in studies conducted both in WA and elsewhere.