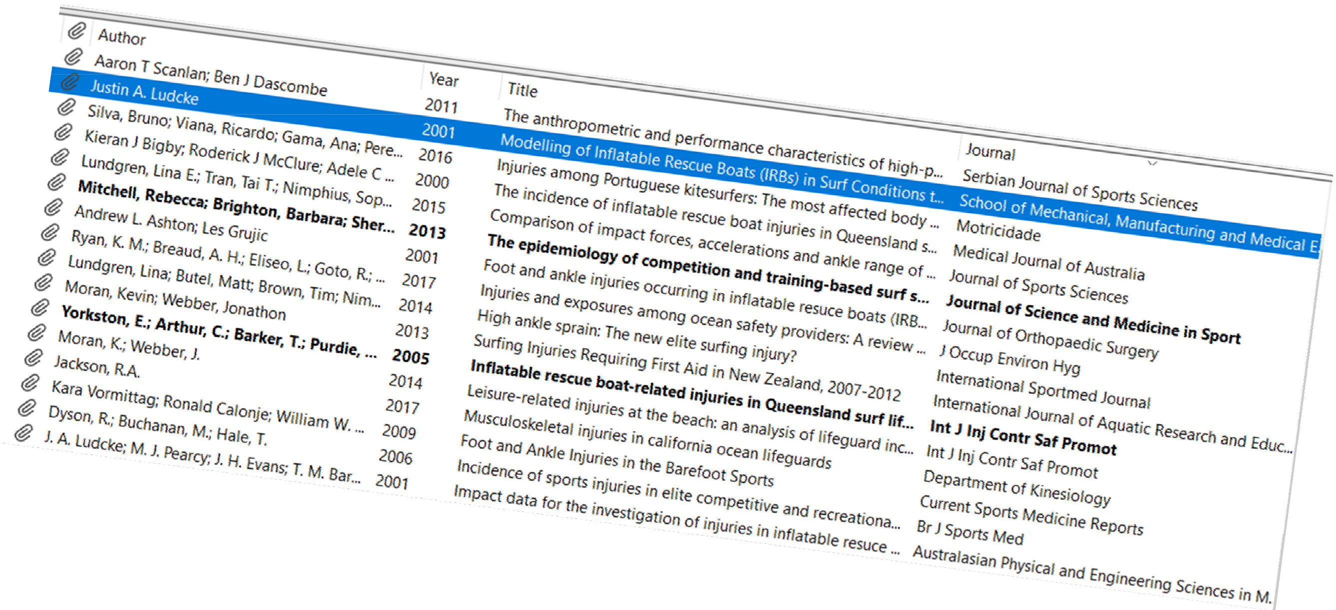
Recreational and competitive surf lifesaving injuries associated with inflatable rescue boats derived from a systematic literature review: Technical report #1 to Surf Life Saving New Zealand (SLSNZ)



Author	Year	Title	Journal
Aaron T Scanlan; Ben J Dascombe	2011	The anthropometric and performance characteristics of high-p...	Serbian Journal of Sports Sciences
Justin A. Ludcke	2001	Modelling of Inflatable Rescue Boats (IRBs) in Surf Conditions t...	School of Mechanical, Manufacturing and Medical E...
Silva, Bruno; Viana, Ricardo; Gama, Ana; Pere...	2016	Injuries among Portuguese kitesurfers: The most affected body ...	Motricidade
Kieran J Bigby; Roderick J McClure; Adele C ...	2000	The incidence of inflatable rescue boat injuries in Queensland s...	Medical Journal of Australia
Lundgren, Lina E.; Tran, Tai T.; Nimphius, Sop...	2015	Comparison of impact forces, accelerations and ankle range of ...	Journal of Sports Sciences
Mitchell, Rebecca; Brighton, Barbara; Sher...	**2013**	**The epidemiology of competition and training-based surf s...**	**Journal of Science and Medicine in Sport**
Andrew L. Ashton; Les Grujic	2001	Foot and ankle injuries occurring in inflatable resuce boats (IRB...	Journal of Orthopaedic Surgery
Ryan, K. M.; Breaud, A. H.; Eliseo, L.; Goto, R.; ...	2017	Injuries and exposures among ocean safety providers: A review ...	J Occup Environ Hyg
Lundgren, Lina; Butel, Matt; Brown, Tim; Nim...	2014	High ankle sprain: The new elite surfing injury?	International Sportmed Journal
Moran, Kevin; Webber, Jonathon	2013	Surfing Injuries Requiring First Aid in New Zealand, 2007-2012	International Journal of Aquatic Research and Educ...
Yorkston, E.; Arthur, C.; Barker, T.; Purdie, ...	**2005**	**Inflatable rescue boat-related injuries in Queensland surf lif...**	**Int J Inj Contr Saf Promot**
Moran, K.; Webber, J.	2014	Leisure-related injuries at the beach: an analysis of lifeguard inc...	Int J Inj Contr Saf Promot
Jackson, R.A.	2017	Musculoskeletal injuries in california ocean lifeguards	Department of Kinesiology
Kara Vormittag; Ronald Calonje; William W. ...	2009	Foot and Ankle Injuries in the Barefoot Sports	Current Sports Medicine Reports
Dyson, R.; Buchanan, M.; Hale, T.	2006	Incidence of sports injuries in elite competitive and recreationa...	Br J Sports Med
J. A. Ludcke; M. J. Pearcy; J. H. Evans; T. M. Bar...	2001	Impact data for the investigation of injuries in inflatable resuce ...	Australasian Physical and Engineering Sciences in M...

By research team members for TE HOKAI TAPUWAE – REIMAGINING SPORTS INJURY PREVENTION

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This report is part of a series of technical reports for the research collaboration between Surf Life Saving New Zealand (SLSNZ) and AUT Sports Performance Research Institute New Zealand (SPRINZ).

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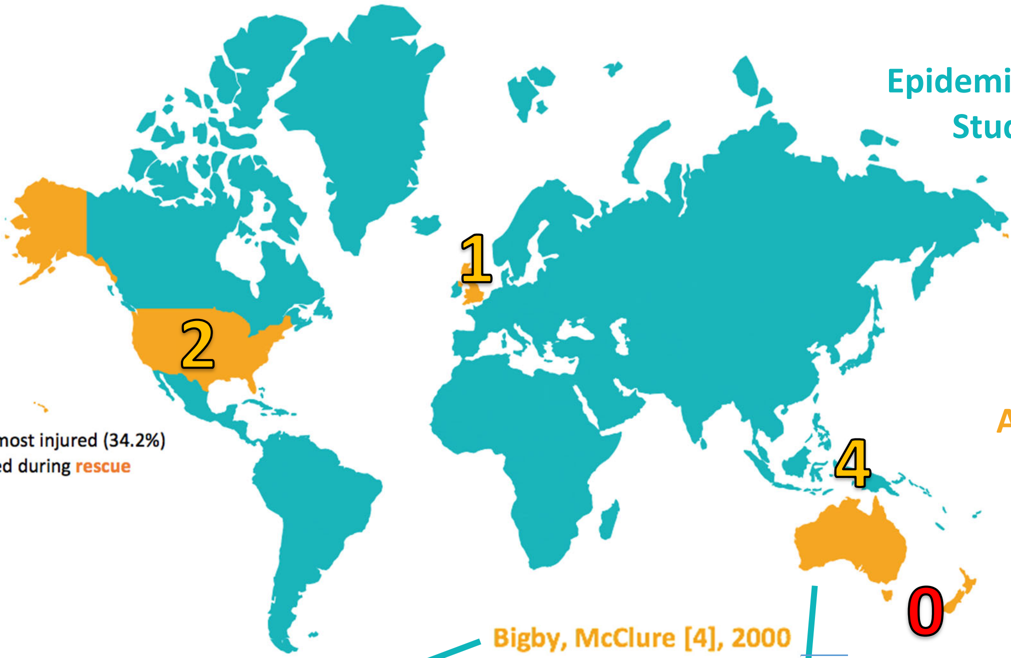
Injuries during surf lifesaving in inflatable rescue boats: evidence from international literature - Fact Sheet



Epidemiological Studies

Lower extremity most injured (34.2%)
35.5% occurred during **rescue**

Australian Surf Life Saving Research

Bigby, McClure [4], 2000

Of 36 injuries, 22 (61%) occurred to right side of the body, with **68%** of those occurring to the lower limb (knee, leg, ankle)

Ashton and Grujic [3], 2001

11/12 Foot Fractures due to right foot strap

Ludcke [25], 2001

Yorkston, Arthur [1], 2005

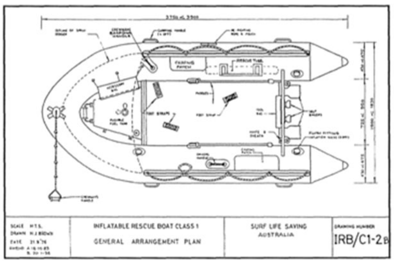
Counterintuitive findings, with more force on the left foot strap, where previous research suggested greater injuries occur to the right limb.
Limitation: many participants did NOT use the right foot strap (modification to technique)

Mitchell, Brighton [2], 2013

Sprains and strains, bruising/contusion, inflammation/swelling, fractures, and dislocations were the most common type of injuries experienced during both **competition** and **training** for IRB events.

Causes of Injury

- Poor Conditions
- Inexperience
- Inappropriate Operation
- Lack of Fitness



Accelerations similar to **motor vehicle accident**

Variation across Australia in foot strap **stance width**, **distance**, and **design**

KEY FINDINGS

- **No published studies for New Zealand surf lifesaving injuries**
- **High incidence of lower extremity injuries to right limb of crew members; consistent with potential issue due to foot strap**
- **Only 3 studies measured forces and accelerations experienced during IRB operation and set-up**

Diewald S.N., Hume P.A. et al. (2019). Recreational and competitive surf lifesaving injuries associated with inflatable rescue boats derived from a systematic literature review: Technical report #1 to Surf Life Saving New Zealand (SLSNZ).

ABSTRACT

Background: Injuries to surf lifesavers operating inflatable rescue boats was identified as a problem by Surf Life Saving New Zealand (SLSNZ). However, the extent and nature of the injuries was not clear from internal SLSNZ reports.

Purpose: To examine effects of factors influencing injury related to surf lifesavers operating inflatable rescue boats and to determine priorities for countermeasure interventions. It was hypothesised that susceptibility and risk of different injuries may vary between patrol duties and competition use of IRB, and between crew and driver.

Methods: The systematic review of international published literature and screening process resulted in 26 articles published from 1971 to 2018 that met the inclusion and exclusion criteria. Epidemiological studies that examined surf lifesaving or water board-sport related injuries were included. SLSNZ provided internal injury reports from 2013-2017, along with the SLSNZ Inflatable Rescue Boat Manual and SLSNZ board meeting minutes.

Results: There was a high incidence of lower limb injuries resulting from inflatable rescue boat operation according to the limited research. Navigating the surf and landing after aerial movements were frequent causes of injury. Susceptibility and risk to different injuries varied between patrol and competition forms of IRB use and between crew members and drivers.

Discussion: Variation in methodological design made it difficult to compare international results. Potential injury risk factors include equipment design, driver experience, and crew technique, strength and experience, maturity and attitude of drivers.

Conclusions: Susceptibility and risk to injuries varied between patrol and competition forms of IRB use and between crew members and drivers. Key risk factors identified from the studies included position in the IRB (crew or driver), lower body strength, and IRB equipment design.

Recommendations:

1. Future injury recordings and studies should focus on investigating occurrence of acute and chronic lower back injuries, as well as presenting a prevention strategy and training program to increase strength in the lower limbs, trunk, and hip musculature.
2. Further research is warranted to quantify injury incidence rates in surf lifesaving and deduce injury mechanisms.

INTRODUCTION

Recreating at beaches is an integral part of daily life in New Zealand, with over 14,000 kilometres of coast line extending across two major oceans, the Tasman Sea and the Pacific Ocean [5, 6]. Surf lifesavers play an important role in keeping the public safe, and recently have come to rely less on traditional non-powered rescue aids and more heavily on powered watercraft; such as the inflatable rescue boats (IRB) to complete open water rescues. Due to their speed and manoeuvrability, IRB*s* are ideal for beach patrol and surveillance. IRB*s* consist of three rigid inflatable pontoons supported by a removable plywood laminate floor, fitted with an outboard motor and additional crewing equipment (e.g. foot straps, hand lines, rescue tube etc.). New Zealand surf lifesavers utilise IRB*s* in over 50% of all rescues per year [7].

Surf Life Saving New Zealand (SLSNZ) is a not for profit incorporated society which coordinates the surf lifesaving activities of all the clubs in New Zealand. This includes the oversight of lifeguard certifications, equipment standards, and member training. The operation of an IRB typically involves two lifeguards; a driver at the stern and a crew person at the bow, while manouvering through the surf simulating or performing a rescue. The crew person is responsible for keeping the IRB balanced through the surf by utilising their body weight, contact points and additional equipment to stay safely inside the boat (e.g. bow ropes, foot straps, hand line). The driver is responsible for manoeuvring the IRB to prevent harm to themselves and their crew. Surf lifesavers participate in regular training to prepare for IRB operations during both patrol and competition.

According to SLSNZ internal injury reports, increased use of IRB*s* in New Zealand may have resulted in an increase in injury incidences [8-12]. The repetitive nature of IRB operations may increase the incidence of acute and chronic injuries, thus negatively impacting the health of surf lifesavers. The pattern of injuries that occur during sport and recreational activities are often examined to identify the number, circumstances, causal factors and mechanism of injury associated with injurious events to quantify the injury burden and to identify potential injury prevention strategies.

Therefore, the aim of this study was to examine effects of factors influencing injury related to surf lifesavers operating IRB*s* and to determine priorities for countermeasure interventions.

METHODS

A systematic review of international published literature was conducted to identify risk factors and evaluate the evidence for the effectiveness of injury prevention countermeasures in IRB*s* using a Haddon's matrix [13] conceptual framework for injury causation (host/ participant, agent/mechanism and environment/community).

Literature Search Methodology

Cochrane Collaboration [14] review methodology (literature search; assessment of study quality; data collection of study characteristics; analysis and interpretation of results; recommendations for practice and further research) was used to evaluate the injury risk factors and potential effectiveness of injury prevention countermeasures in IRB*s*.

The review was conducted in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) statement guidelines [15]. A systematic search of the research literature was undertaken for studies that investigated injuries occurring during surf-sport related activities, specifically focused on surf lifesavers.

Search Parameters and Criteria

Studies were found by searching Pubmed and Sports Discuss electronic databases from 1971 to December 1st 2018 using the Boolean search phrases (*surf OR lifeguard OR lifesaving) AND (boat OR inflatable OR rescue OR craft OR *board* OR IRB) AND (injur*). Additional studies were found by reviewing reference lists from retrieved studies. SLSNZ provided injury reports from 2013-2017, along with the SLSNZ Inflatable Rescue Boat Manual and SLSNZ board meeting minutes.

Papers were selected based on title, then abstract, and finally text. Manual searching of reference lists and the 'Cited by' tool on Google Scholar were used to identify additional articles. These were included in this review. Papers were excluded if their content: (i) was unavailable in English; (ii) was unavailable in full text format; (iii) did not provide additional information for any of the identified sections and subsections of this review. Inclusion criteria for all articles were: (i) reported data for risk factors on surf lifesaving injury rate or severity; or (ii) reported data for risk factors on water-based board sports injury rates or severity. Articles that examined surf lifesavers of any age, sex, or activity level were included. Studies were excluded that did not involve injuries occurring on the water, or while participating in other surf-related sports (e.g. sports that utilized a paddle were excluded). Studies involving drowning injuries were also excluded.

The search of electronic databases and the scan of article reference lists revealed 145 relevant studies of which five were duplicates. After selection for inclusion criteria and elimination based on exclusion criteria, 26 were left for inclusion into the final review. Figure 1 shows the flow of information through the systematic review.

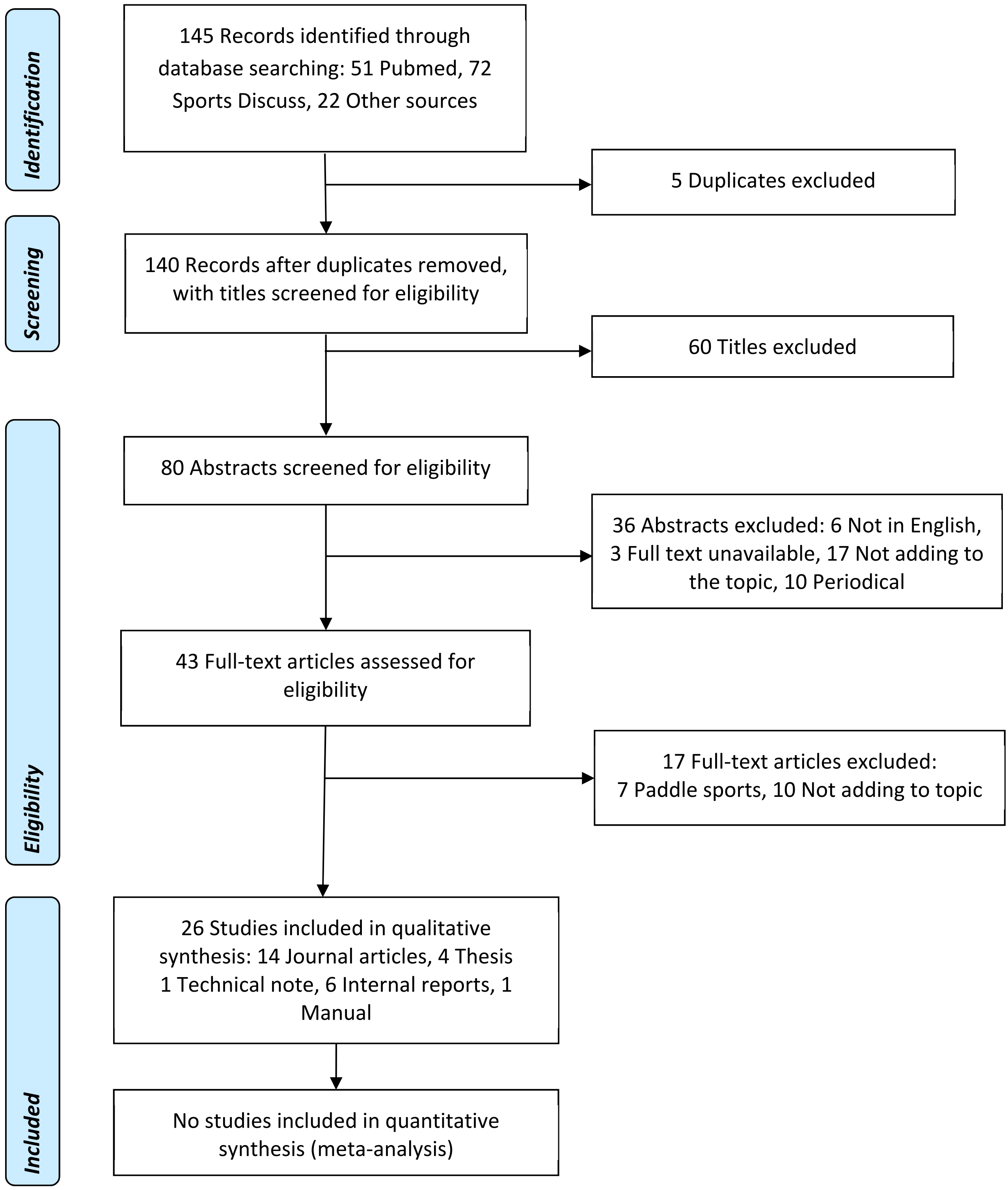


Figure 1: Flow of information through the systematic review

Data Extraction, Assessment of Study Quality

Data extracted from studies in this review including study name, aim/focus, study design, participants' characteristics, methodological quality, interventions, outcome measures, and injury risk factor statistic results.

Authors from the current study independently assessed each article using a 6-item custom methodological quality assessment scale where 0=clearly no and 1=clearly yes. The six items included: (1) study design (0=prospective cohort or cross-sectional study, 1=case control - randomised); (2) study samples (0=no control or control not greater than 4:1, 1=adequate); (3) participant characteristics (0=not given, 1=sex and age reported); (4) sport details (0=not detailed, 1=detailed); (5) outcome variables (0=not appropriately defined or reported, 1=appropriate and tabulated); (6) statistical analyses included adjusted OR and/or RR adjusted for covariates (0=no, 1=yes). Covariates included age, sex, type of IRB participant, weather condition, and self-reported experience level. The quality scores based on the paper selection criteria ranged from 1 to 6 and are shown in curved brackets in Table 1. Details of ratings of the other publications (e.g. theses, internal reports) were not provided in the table as they were all zero.

Analysis and Interpretation of Results

There was a large range in the methodological design, sample size, and injury risk factors investigated. The large variation in definition of outcomes, injury, and factors between studies made combined analysis difficult for some risk factors. Meta-analysis was therefore not undertaken due to the large variability in types of study (e.g. cohort, retrospective) and participants (sex, experience level, patrol versus competition).

RESULTS

Table 1 summarises five injury reports, one intervention study, four theses, one technical note, and 16 other studies. Four articles [1, 3, 4, 16] detailed risk factors specifically surrounding surf lifesavers operating IRBs, four studies [2, 16-18] investigated risk factors surrounding surf lifesavers in all activities, five studies [19-23] detailed risk factors and injury incidences of other water-based sports (e.g. kitesurfing, windsurfing, surfing) and three studies [1, 24, 25] measured potential injury causing loads occurring in IRBs.

The databases on ocean lifesaver injuries were scarce and the available injury data likely underestimate the prevalence of musculoskeletal injuries in this population (Note the international terminology of ocean lifeguards for USA versus surf lifesavers for NZ and Australia). The quality of the studies was low (Table 1) due to poor study design, low sample numbers, and lack of information on covariates. For example, the reports on the Surf Life Saving New Zealand (SLSNZ) injury database for 2013–2018 had limited quality information due to low reporting rates [8-12].

Injury Epidemiology

Surf lifesaving epidemiological data were available only for Australia [1-4], USA [16, 18], and New Zealand [8-12]. Retrospective data came from hospital databases [3], workers' claim databases [4, 18], surf lifesaving internal databases [2, 4, 18], injury reports [8-12], and retrospective questionnaires [1, 4, 16, 18].

Retrospective questionnaires were the most popular sources of epidemiology data in Australia [1, 4]. Hospital databases were also used to obtain injury epidemiology data in Australia, however only at the regional level [3]. Furthermore, information gaps of injury description and historical diagnosis existed in most databases. This information was combined with other sources of epidemiology information in order to paint a full injury picture.

A retrospective investigation of WorkCover NSW (New South Wales) injury claims from 1989 to1998 totalling $1,734,788 AUS for surf lifesavers indicated most injuries occurred in inflatable rescue boats (36.3%) [17]. This study led to the development of a national trial injury reporting system for surf lifesaving in Australia (SLSA) in order to obtain better epidemiological data. Whilst it was recommended that crew experience, a full description of the incident, and detailed mechanisms of injury should be included to improve injury reporting, medical personnel specified the form was too long to complete under time constraints, resulting in reduced quality of reporting by surf lifesavers. Moreover, the validity and reliability of the SLSA database had not been assessed, limiting the results. Nevertheless, it was the only available surf-related incident database in Australia at the time [2].

Only two studies to date were found obtaining lifeguard information in the United States; utilising worker's compensation [18], hospital databases [18], and retrospective questionnaires [16, 18]. Questionnaires had low response rates, limiting the study sample size.

Injury data from Surf Life Saving New Zealand (SLSNZ) (2013–2018) were for citizens and surf lifesavers combined [5, 6]. Injury reports provided by SLSNZ specified surf lifesaver-specific injuries for each competitive season from 2013 to 2018. However, the injury report form, from which the information is collated, did not allow for detailed accident descriptions or mechanisms [8-12].

Nature of Injury

Australian epidemiological studies from 1989 to 2011 showed an increased risk of injury while operating an IRB [2, 4, 17], with high incidences of lower-limb injuries [4]. Knee, lower leg/ankle, and foot injuries accounted for over 50% of total injuries reported in California, although causes of injuries were not reported [16]. Soft-tissue injuries accounted for most of the ankle injuries, followed by fractures [2-4]. Lacerations, sprains, suspected sprains, and fractures accounted for most of the IRB-related injuries reported in New Zealand, with IRB nationals resulting in 45.8% of all serious injuries during 2013-2018 despite occurring in only 7.9% of all competitors [8-12]. Inflatable rescue boats accounted for 19.5% of competition injuries and 29.9% of training injuries from 2003 – 2011 in Australia; sprains (16.0%), strains (15.3%), bruises (12.4%), inflammation (12.3%), and fractures (10.3%) the most frequent [2]. There was a greater proportion of injury on the right side of the body and occurring mostly to the crew member [3, 4].

In New Zealand from 2014 - 2018, the most commonly injured age group ranged from age 16 to 21 years [8-12]. However, a retrospective epidemiological review of competition and training-based surf related injuries in Australia from 2003-2011 showed increased training-related injury rates in the older population (35 years or older) compared to the youth population (6 to 34 years). Furthermore, a retrospective survey of California ocean lifeguards identified that 61% of the 431 respondents experienced an injury while volunteering (on patrol). Increased age, increased years of experience, and student employment status were significantly associated with increased injury occurrence.

Circumstances and Mechanisms of Injury

Most IRB-related injuries occurred while navigating over waves. The most common contributing factors for the injuries were returning to the shore and negotiating the break [2]. A total 25.5% of all IRB-related injuries were reported as having occurred during landing while attempting to navigate a wave. "Landing" was further identified as the cause of 33.3% of ankle and 50% of foot IRB-related injuries [8-12].

Crew members seem to have a greater risk of injury [4] compared to IRB drivers, particularly to the right lower-limbs [3]. The mechanism of injury may be influenced by the crew member foot straps [3, 26]. Moreover, increased injury rates to the right side of the body could be due to torsional, compressive, or shear forces transmitted from the foot straps. Foot straps were reported as contributing to the cause of injury for 8.3% of ankle and 25% of foot injuries in New Zealand [8-12]. Thus, surf lifesavers operating IRBs seem to sustain characteristic injuries at a moderately high rate; and the predominance of right-sided lower limb fractures, with a tendency towards the crewmember rather than the driver, suggest the crew member may be in a poorly braced position at the front of the craft [4].

A limited number of articles have investigated possible mechanisms of IRB injury through data collection and computer simulation. Only two studies measured loads experienced by IRBs and associated crew and driver: accelerations of the IRB [24, 25], and ground reaction forces felt through the crew members' feet at wave impact [1]. No published articles were found that directly measured tibial accelerations or rotations of the crew or driver. However, tibial accelerations, ground reaction forces, and rates of acceleration, have been analysed in windsurfing [19, 20] and traditional surfing [22].

IRB Experience

The literature review found conflicting results surrounding the relationship between age and IRB-related injury risk [2, 4]. It may be more informative to assess the relationship between years of experience and injury occurrence [17], yet no studies to date have examined this. Future research should examine the relationship between age, years of experience, and injury occurrence in surf lifesavers operating IRBs.

Driver and Crew Technique

Driver practices and technique are likely important to reducing injury risk. Whilst organizations such as SLSNZ provide information on IRB skills in their training manuals, there have been no evaluations of the knowledge, attitudes, or behaviour changes as a result of the education and IRB crew training [7]. Defined, evidence-based procedures (and training of such) while negotiating the break and returning to shore is pertinent in maintaining crew member safety, and a potential factor in reduction of injury. Moreover, 59.2% of IRB-related injuries in a season were contributed to inappropriate operation, inexperience, and inadequate training [4]. Assessing current training standards and their effects on the biomechanical loads experienced by crew members, as well as compliance of those standards, would be essential to determining aetiologies of injury.

Driver and Crew Strength

According to a surf lifesaving questionnaire, lack of fitness (note: note quantified in any way) has been identified as a contributing factor of IRB-related injuries [4]. Muscular strength and stability play an important role in injury prevention and protection of the lower limb ligaments and tendons. Therefore, there may be a need for improved physical fitness standards and specific training for lifeguards [16]. The required strength necessary for operation of an IRB has been investigated, however no strength assessments were identified for operation while on the water (only sand-based activities) [27]. Furthermore, there have been no strength intervention studies in the surf lifesaving population [28].

Lower extremity strength, power and mobility training may support in reducing the incidence of injuries occurring to surf lifesavers operating IRBs. Evidence exists of a clear correlation in water board-sports between incidence of lower limb injuries due to landing aerial movements [19-23]. Studies have highlighted the importance of physical strength and preparation to reduce these injuries in other sports [22, 27, 28], with a focus on training athletes to handle compressive forces in dynamic landing situations. An understanding of the strength required to operate an IRB safely, and the effects on balance at the ankle and knee joints may play a key role in developing injury prevention programmes and standards for surf lifesavers. Performance characteristics of elite junior surf lifesavers (age 13.8 ±1.5 years) exist, yet no studies have investigated physical qualities of surf lifesavers operating IRBs (age > 15 years) [29]. Thus, future studies should focus on presenting a prevention strategy and training program to increase strength in the lower limbs, trunk, and hip musculature.

Equipment

Inflatable Rescue Boat Design

SLSNZ is a world leader in the field of IRB operations, with IRBs involved in more than 50% of all rescues in New Zealand each year. Arancia is the only SLSNZ approved IRB manufacturer. However, high variability was reported in IRB designs and foot strap locations across Queensland, even amongst similar models [24]. Understanding the design of the current IRB model is key in identifying the cause of injuries that occur within the boat.

The location of the foot straps plays an important role in the biomechanics of crew member technique during operation [24]. The stance angle, width, and direction place varying biomechanical limitations on the crew member, and the optimization of these attributes has a large degree of inter-variability.

Foot straps play a significant role in the safety of the crew member by decreasing the susceptibility to ejection from the IRB. Although previously suspected as a direct cause of lower limb injury [3], the removal of the right foot strap showed no signs of reduced dorsiflexion, a known risk factor of ankle injuries [25]. Nevertheless, the removal of the right foot strap was recommended in New Zealand in 2010, 2014, and mandated in 2017 [26]. No current knowledge exists of adherence in IRB design across clubs in New Zealand. It is important to understand if standards have been met, and whether this may be contributing to increased injuries amongst clubs. In addition, it has been shown that crew and drivers adopt different techniques, regardless of available equipment [1]. Therefore, it would be beneficial to examine whether the manufacturers foot strap locations have been altered in any of the clubs or regions within New Zealand, as well as the respective crew training standards to understand possible causes of injury.

In one study, increasing the floorboard foam thickness to at least 20 mm, regardless of density, provided reduction in the impact to the crew. However, influences of other factors such as cost, wear resistance, and abrasive effects have not been established [24]. The effects of foam density and other floorboard design characteristics need to be further examined.

Personal Safety Equipment

Currently, SLSNZ mandates the use of personal floatation devices and helmets while operating an IRB. However, there have been no studies examining the effectiveness of personal protection equipment (PPE) to prevent injuries to lifeguards while operating IRBs. Whether knee or ankle braces, or the use of helmets can prevent injury or reduce the severity of the injury in surf lifesaving is unknown. However, use of PPE and quick release systems may offer possibilities for education [19].

Weather and Water Conditions

Inclement weather with reduced visibility and wave conditions could be key factors contributing to increased risk of injury, particularly due to the unpredictability [20]. Wave size and type, and wind speed and direction may increase injury risk, particularly during competition where boat speed is applied, often to excess [17]. 'Moderate sea conditions with an 'average chop' can increase injury risk given 16/21 patients with injuries reported this as a factor in their injury cause [4]. ‘Overcast’ weather should be avoided if possible when operating IRB*s* given 10/21 patients with injuries reported this as a factor in their injury cause [4]. However, a high percentage of rescues occur during inclement weather, therefore other methods of protection against adverse conditions should be investigated [5, 6].

Education Interventions

There were no studies of the effectiveness of education or training interventions to reduce surf lifesaving injury frequency or magnitude. The nature of the education programme and the target audience are likely to be key to success. Increased risk taking as a result of confidence after having taken lessons may increase injury risk and severity. It is speculated that less experienced athletes may sustain more severe injuries [19]. However, anecdotally, overconfidence of inexperienced drivers/crew is considered a contributing cause of injuries.

DISCUSSION

Quality Of The Research Studies And Epidemiological Data

The aim of this study was to examine effects of factors influencing injury related to surf lifesavers operating inflatable rescue boats and to determine priorities for countermeasure interventions. There was limited research directly related to surf lifesaving and IRBs and injuries or risk factors. Variation in methodological design made it difficult to compare results. For example, whilst SLSNZ provided injury reports from 2013 to 2017, there were large gaps in the data. Report content suggested that crew members and drivers could have different injury risk profiles, and therefore a position-specific approach to injury prevention could aid in reducing injuries; however, there was no evidence for either suggestion. The review of studies demonstrated a need for quality epidemiological studies and analysis of IRB injuries to quantify acute and chronic injury occurrences and impacts of surf lifesaving participation.

Priorities for Countermeasure Interventions

There should be consideration of the potential for effectiveness of injury prevention countermeasures included unalterable host (e.g. age and sex) and environmental factors (e.g. weather). Interventions should focus on affecting modifiable factors such as education, protective equipment, equipment design/set up, and limiting the IRB participant’s exposure to poor run conditions and planning. Ideally randomized controlled trials or studies evaluating cost to benefit ratio of countermeasure interventions are needed to guide decisions on which strategies should be implemented for IRB activities. Based on the strength of the evidence, priorities for countermeasure interventions could include weather reports, course planning, education on injury prevention strategies, boat equipment improvements, use of digital assets and use of protectors.

The design of competition courses should be considered. Limiting excess speed through constraints-based course design may reduce injury risk [3, 4].

Helmets should be worn to limit the severity of a collision following an ejection from an IRB. Helmet design should be tested to ensure visibility of crew members and drivers.

Further investigation is required to establish whether design standards have been maintained by all clubs, and whether aftermarket modifications are contributing injury factors. Foot strap locations should be made adjustable to account for different body dimensions of users. Adjustable and comfortable straps should be standardized across New Zealand. Consideration should be given to the location, type and adjustability of foot straps, to assist crew members and drivers to remain inside the IRB during operation.

The frequency of weather reports could be increased including water conditions and include educational programs for beginners how to check current weather and surrounding wave conditions and how to interpret the conditions to make necessary adjustments.

Educational videos could be targeted at beginners for screening at key locations could help increase knowledge and awareness of risks and injury prevention strategies. Video length needs to be considered. Key messages for beginners to include safety rules and key safety protocols (helmets, braces, PFDs), important skills, hazard awareness, understanding the weather and water conditions and how these can affect personal safety, boat performance and manoeuvrability.

Use of digital assets such as cell phones, web sites and TV screens mounted at facilities to provide injury prevention message information could be useful.

An implementation plan for countermeasure interventions for IRB needs to consider the current socio-cultural and technological context. Injuries result from a set of circumstances and pre-existing conditions that can be considered using Haddon’s matrix [13] that provides a conceptual framework for injury causation

Silva et al. (2016) [23] Retrospective epidemiology review Injuries among Portuguese kite surfers. (4) *Injury and treatment.*	• Investigated incidence of injuries to Portuguese kite surfers to better understand associated injury mechanisms. • Questionnaire web-based - 12 months: general information, physical activity, protection systems, injuries, consequences of injuries. • 87 respondents (5 female, 82 male) 34.2 ±9.1 yrs old; 4.9 ±3.2 yrs experience.	• 56.3% assumed use of protective equipment 53 reported injury (35 reported multiple injuries). • Superficial wounds and sprains most reported (18.5% each). • Knee and lumbar most injured (12.4% and 11.2%) - Lower body = 52.9%. • Majority occurred while landing (n=26), maneuver (n=22), or (n=19) jump.	• Assumption that kite surfers with an initiation course, more yrs experience, that perform warm-up and use protective equipment have less injuries was not verified.
Reilly et al. (2005) [28] [Thesis] Fitness training programme for RNLI beach lifeguards operating rescue WC and IRB. *Body – motor control.*	• Two training programmes developed based on previous 1RM measurements obtained during frequently preformed IRB-related tasks. • No participants included in this study.	• Training programme aimed at RNLI BLG to improve upper and lower body strength.	• Two training programmes introduced: beach-based and gym-based. • No data were collected, and the programmes were not tested for effectiveness. • No water-based activities included in the programmes.
Reilly et al. (2004) [27] [Thesis] Questionnaire, systematic review, simulation. Fitness requirements for RNLI beach lifeguards to operate rescue watercraft (RWC) and inshore rescue boats (IRB). *Body – motor control.*	• Questionnaire measurement of physiological demands of tasks. • Task simulation and replication (n=10). • External load (n=3).	• Established the most physically demanding tasks involved in operating RWC and IRB. • Determined external loads involved in working with RWC and IRB. • Participants indicated the most demanding tasks associated with IRB were: Lifting trailer to launch IRB, pulling IRB off trailer, pulling and lifting IRB, pulling and lifting trailer, dragging IRB on beach, launching IRB, boarding from water, working in surf.	• No water-based measurements were conducted.
Scanlan et al. (2011) [29] Cross-sectional. Anthropometric and performance characteristics of high-performance junior lifesavers.	• Anthropometric (stature, body mass, arm span) and performance (vertical jump height, 5m and 20m sprint times, peak velocity, flexibility, 505 agility, estimated VO2 max, chest strength,	• Identified sex differences. • Males: greater stature, arm span, vertical jump height, VO2max, and back and leg strength. • Females: greater hamstring flexibility.	• All < 15 yrs. Growth and maturation can affect performance and anthropometric characteristics up until 18 yrs. • IKD is a poor measure of dynamic strength, which is required of most SLS tasks.

(4) *Body – motor control.*	back and leg strength (IKD) characteristics. • High-performance Australian junior lifesavers. • 33 males: 13.8 ±1.5 yrs; 164.3 ±9.4 cm; 54.5 ±11.2 kg. • 30 females 13.5 ±1.6 yrs; 157.7 ±9.1 cm; 49.5 ±9.6 kg.		• More research needed to develop standard values within the population of athletes.
Lundgren et al. (2014) [21] Case series, retrospective. High ankle sprain: The new elite surfing injury? (3) *Technique. Injury and treatment.*	• Examination performed on site, via palpation, anterior drawer test, talar tilt test, squeeze test, and external rotation test, and sent for MRI scan. • Official video used to describe injury situation. • 2D video recording (Tracker 4.80) for variables. • case 1: 19 yr male case 2: 20 yr male	• Two cases of acute ankle injuries from aerial maneuvers sustained at a professional surfing event. • Cases differed in severity. • Training should be guided to develop and evaluate and target capacity for athletes to handle compression forces and dynamic landing situations. • Training should include landing exercise and movement preparation to increase ability to absorb compression forces, and increase lower extremity strength, power and mobility in order to transfer the high energy through the lower limbs.	• Only 2D and could not accurately describe foot position at landing.
Ludcke et al. (2001) [24] Thesis [Systematic review, Case-control study (floorboard), In-Lab Assessment, In-lab recreation simulation]. Modelling of IRBs in surf conditions to reduce injuries. *Equipment. Technique.*	• Systematic review. • Design analysis of IRBs in Queensland. • Field tests of accelerations of IRB. • 3D simulation model.	• Identified injury causes and proposed processes that may reduce instances and severity of injury to surf lifesavers during IRB operation. • Simulated wave, loading the boats flex around a pivot point determined by the position of the hinge in the floorboard (close to where the foot strap locations usually are placed. • Accelerations felt by crew exhibited similar characteristics to road vehicle accidents. • Attributes of optimum foam thickness and density were found, and optimum crewing positions. • Observed lack of adherence to SLSA foot strap standard impeded successful epidemiological and modelling outcomes.	• Uniformity of boat setup needed to highlight influence of implementing changes to boat design. • Accelerations were measured at the floorboard on the boat, not on the crew member themselves.

Ludke et al. (2001) [25] Case series, Technical note. Impact data for investigation of injuries in IRBs. (2) *Equipment. Technique.*	• Custom built accelerometer and data logging system (accelerometer attached to floorboard, just behind the hinge point). • Visual analysis of waveforms to identify wave impacts.	• Identified causes of injury and proposed processes that may reduce instances and severity of injury to surf lifesavers during IRB operation - particularly accelerations experienced by crew members and IRB. • High impulse (average 23g pulse for 25ms) exerted by each wave (rather than peak acceleration) - major factor in injury causes. • 50g is adequate to capture necessary spikes in accelerations.	• Low sampling rate. • No synchronization method between video and accelerometer. • Accelerometer was removed after each trial therefore possible error in calibration of direction. • Visual analysis of wave form not validated. • No angular velocities measured. • Noise not removed from data. • Study determined sensor thresholds. • Impact data analysis was performed on one-off events, where impacts associated with IRBs occurs repeatedly every time the boat travels over a wave.
Yorkston et al. (2005) [1] Case-control study, cross-sectional study IRB-related injuries in Queensland surf lifesavers: epidemiology - biomechanics interface. (3) *Equipment. Technique.*	• Developed epidemiological and biomechanical methodologies and measurement instruments that identify and measure the risk factors. • Questionnaire paper based. • Age, physical characteristics, training, and experience. • On-board video camera (still images of crewing technique). • 10 minutes of IRB operation. • Custom-built piezo electric force plate. • Crewman's foot straps orientated as per IRB (Arancia 380) manufacturers specifications were fixed to superior surface of force plate. • 15 Queensland surf lifesavers, 12 males.	• Described relationship between epidemiological and biomechanical factors in casual pathway of IRB-related injuries in Australian surf lifesavers. • Conceptual model of RF: Wave forces, boat forces, forces transferred at impact, physical attributes of IRB, IRB crewing techniques, training, experience, forces applied to host. • 404.5N max force for anterior left foot. • Right side measurements smaller and closer in range than left side (149.0N posterior). • Summation of forces showed left transducer registered 2 x forces as right side.	• Only measured GRF, no accelerations (no kinetic energy can be calculated). • Would have been beneficial to measure centre of mass. • Less force on left side with previous research suggested greater injuries occur to right limb. • Many participants did not use right foot strap (modification to technique). • Exact forces unknown, magnitude of forces was referenced.
Lundgren et al. (2015) [22] Lab research, Case series, Cross-sectional. Comparison of impact forces, accelerations and	• Described impact forces, accelerations, and ankle range of motion in five different landing tasks used in training and testing for competitive surfing athletes. • Inertial measurement units (XSENS up to	• Moderate to high correlation (r=0.69–0.82, $p \leq 0.01$) between relative peak landing force 2.3-17.3 N/BW and tibial resultant peak acceleration 5.3g to 21.4g. • ICC of tibial accelerations were most satisfactory (0.63 to 0.93).	• Suggested that those with less static dorsiflexion range of motion must use more of their total range to perform the landing. • Limited acceleration range for IRB comparison. • Similar potential for decreased dorsiflexion in IRB due to similar landing (board on water).

ankle range of motion in surfing-related landing tasks. (4) *Equipment. Technique.*	18g) placed at mid-foot and mid-tibia sacrum, and T8. • Force plates. • Performed battery of 5 landing tasks. • Analysed resultant peak accelerations, vertical force (max peak). • 11 male professional surfers 24 ±6.9 yrs, 1.8 ±0.5 m, 70 ±9.0 kg.	• Tibial acceleration sensor placement was more reliable, and better represents vertical peak force compared to sensors at sacrum and T8. • Different kinematic landing strategies between tasks. • A reason for decreased dorsiflexion range of motion in trampoline landing condition with a board was the athlete's feet need to be in board contact during landing preparation.	• Recommendation that magnitude of load quantified in intervals, rather than exact numbers. • Limited sampling frequency (600 Hz). • Tibial inertial sensors can be applied to provide an estimation of peak impact in landing tasks. • High correlations in basic landing tasks. • The effect on kinetics of landing seemed substantial and needs further attention in researching board sport performance.
Inflatable Rescue Boat Training Manual. (2018). [7] *Knowledge*.	SLSNZ specific inflatable rescue boat training manual for 2018.	• Manual information includes equipment standards, crew and driver training, and operation information (fuel, communication, maritime regulations, IRB setup, basic skills and techniques for crew and driver specific, rescues, IRB closedown).	• Equipment specifications specify parts, but do not specify location of foot straps. • IRB set-up does include lifting techniques for heavier equipment (engine, pontoons, etc.). • Basic skills for crew and drivers were good, but limited information was provided, around crewing position when navigating a wave (e.g. feet placement). • Limited information regarding landing techniques was provided for landing after going over a wave (e.g. bracing for impact).
Corbett et al. (2010) [26] Technical Report. Board of Life saving - Minutes: IRB Review. *Knowledge*.	• Board meeting discussion around IRB-related training, education, culture, gear and equipment, and IRB injury data.	• Changes included: Removal of right foot strap mandatory. • Must replace all remaining foot straps with adjustable. IRB injury data needs to be improved. • Training and Education IRB Crew Certificate - Prior to any practical crew, training candidates must complete IRB theory session. - Advised that minimum hours of training be implemented but denied. - IRB crew learner guide needs clear process of how IRB crew training is to be carried out (lesson plans). - Recommended candidates must be 16 (kept it 15). • IRB driving certificate - Recommended hourly requirements but denied. • IRB training certificate - Kept standard of having to assist training one squad with	• More clarification needed for reasons to deny recommended training and education changes. • What evidence to support "claim". • What evidence to support removal of right foot strap. • Was replacement of all foot straps with adjustable straps carried out by clubs? followed up by SLSNZ? • No suggestions for how IRB injury data should be improved.

		a qualified mentor. - Accredited IRB trainers must attend nationally set IRB trainer workshop. • Claim: it is not the equipment, but the person in control of the boat.	

Table 2. The temporal components of pre-event (primary injury prevention), event (secondary injury prevention) and post-event (tertiary injury prevention) phases were considered against human, agent and environmental factors. When considering IRB injuries, the key question is: "Where will injury prevention interventions be most effective within this matrix?" In selecting injury prevention countermeasures there needs to be: identification of the key problem hazards and resulting injuries; consideration of design change that ideally will not result in individuals having to take action each time the countermeasure is used; ensuring the countermeasure is accepted for use by the participants; ensuring there is a positive cost to benefit ratio; no unwanted side effects or misuse of the countermeasure; and the effects of the countermeasure can be measured. The effectiveness of common injury prevention countermeasures such as education and behaviour change programmes, environmental/equipment design changes, and regulation/legislation changes need to be evaluated. Key risk factors that countermeasure interventions should focus on include crew and driving techniques, education, equipment design, and physical fitness/ability. SLSNZ could also benefit from specific evidence-based injury prevention strategies including strength training, technique modifications, and equipment design changes.

Limitations and Future Recommendations

Epidemiological studies have identified risk factors and injury incidence rates amongst surf lifesavers and found a greater percentage of injuries are occurring to the crew members in IRBs. These studies were further investigated using simulation to identify possible injury mechanisms, aetiologies, and methods of reduction of injury. However, rule changes have since been implemented in New Zealand, including the removal of a foot strap and the mandating of helmets. Yet, there have been no studies to date investigating the effects of these prevention methods and rule changes.

Studies have attempted to analyse lifeguarding injuries in New Zealand via the Surf Life Saving New Zealand (SLSNZ) incidence reporting database. Yet, no studies to date have investigated injuries occurring to surf lifesavers in New Zealand. Furthermore, SLSNZ patient and incident reporting is currently in paper format only. Injury counts are most likely greatly underestimated with evidence of low reporting rates and lack of detailed descriptions. Therefore, it is recommended that a more in-depth epidemiological review be conducted to further understand the problem. It would be beneficial to conduct a retrospective survey to identify injuries that may have not been reported (i.e. chronic). Details surrounding the cause of injury and professional diagnosis are unclear, therefore future reporting forms should include this information. Further, the reported incidences only account for acute injuries; chronic injuries are not regularly reported to SLSNZ. Nevertheless, medical costs and diminished quality of life related to chronic injuries can be substantial. Therefore, it may be of interest to investigate SLSNZ member acute and chronic injuries in detail via a retrospective survey to assess impacts of surf lifesaving participation. Future injury recordings and studies should focus on investigating occurrence of acute and chronic lower back injuries, as well as presenting a prevention strategy and training program to increase strength in the lower limbs, trunk, and hip musculature.

Potential risk factors for sustaining a severe injury in sport include; the nature of the sport itself, age, competition level, and position. There is limited research relating to surf lifesavers, although there is evidence of high injury incidences amongst volunteers and athletes. Further research is warranted to quantify injury incidence rates in surf lifesaving and deduce injury mechanisms.

CONCLUSIONS

The mechanisms of injury prevention strategies related to surf lifesavers operating IRBs was examined. The susceptibility and risk to different injuries varied between patrol and competition forms of IRB use and between crew members and drivers. The main injuries were sprains, fractures, and lacerations to the lower limb. The crew member experienced a greater number of injuries compared to the driver. The mechanisms of injury were navigating the surf and landing after aerial movements. Risk factors include age, mode of operation (patrol vs. competition), and equipment design. The injury prevention strategies included strength training, education and technique training, and equipment modifications.

SLSNZ would benefit from easily implemented and cost-effective injury prevention countermeasures that are effective at reducing injury rate and severity. It is clear these is a high incidence of lower limb injuries occurring during IRB operation, possibly due to technique, strength, experience, and equipment design. However, the findings from this review provide an indication of the limited surf lifesaving specific research. SLSNZ provided injury reports from 2013-2017, although large gaps in the data demonstrate a need for further epidemiological studies and retrospective analysis of IRB injuries in New Zealand to quantify acute and chronic injury occurrences and impacts of surf lifesaving participation. SLSNZ could benefit from specific evidence-based injury prevention strategies including strength training, technique modifications, and equipment design changes. SLSNZ would benefit from research to fill gaps in current literature surrounding IRB injuries in support of implemented injury prevention strategies.

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REFERENCES

1. Yorkston, E., et al., *Inflatable rescue boat-related injuries in Queensland surf life savers: the epidemiology - biomechanics interface.* Int J Inj Contr Saf Promot, 2005. **12**(1): p. 39-44.
2. Mitchell, R., B. Brighton, and S. Sherker, *The epidemiology of competition and training-based surf sport-related injury in Australia, 2003–2011.* Journal of Science and Medicine in Sport, 2013. **16**(1): p. 18-21.
3. Ashton, A.L. and L. Grujic, *Foot and ankle injuries occurring in inflatable resuce boats (*IRB*) during surf lifesaving activities.* Journal of Orthopaedic Surgery, 2001. **9**(1): p. 5.
4. Bigby, K.J., R.J. McClure, and A.C. Green, *The incidence of inflatable rescue boat injuries in Queensland surf life savers.* Medical Journal of Australia, 2000. **172**(10): p. 4.
5. Moran, K. and J. Webber, *Surfing Injuries Requiring First Aid in New Zealand, 2007-2012.* International Journal of Aquatic Research and Education, 2013. **7**(3).
6. Moran, K. and J. Webber, *Leisure-related injuries at the beach: an analysis of lifeguard incident report forms in New Zealand, 2007-12.* Int J Inj Contr Saf Promot, 2014. **21**(1): p. 68-74.
7. *Inflatable Rescue Boat Training Manual*. 2018, SLSNZ: PO BOX 9205. p. 1-71.
8. Dalton, P., *Serious Injury Report 2013-14 Season*. 2014, SLSNZ. p. 1-5.
9. Dalton, P., *Serious Injury Report 2017-18 Season*. 2018, SLSNZ. p. 1-6.
10. Dalton, P., *Serious Injury Report 2016-17 Season*. 2017, SLSNZ. p. 1-7.
11. Dalton, P., *Serious Injury Report 2015-16 Season*. 2016, SLSNZ. p. 1-7.
12. Dalton, P., *Serious Injury Report 2014 - 15 Season*. 2015, SLSNZ. p. 1-8.
13. Haddon, W., *A logical framework for categorizing highway safety phenomena and activity.* J Trauma, 1972. **12**: p. 193–207.
14. Higgins, J.P.T. and S. Green, eds. *Cochrane handbook for systematic reviews of interventions 4.2.6. The Cochrane Library*. Vol. 4. 2006, John Wiley & Sons, Ltd: Chichester, UK.
15. Moher, D., et al., *Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement.* Annals Internal Medicine, 2009. **151**(4): p. 264-269.
16. Jackson, R.A., *Musculoskeletal Injuries in California Ocean Lifeguards*, in *Department of Kinesiology*. 2017, California State University: ProQuest LLC. p. 58.
17. Erby, R., R. Heard, and K. O'Loughlin, *Trial of an injury reporting system for surf life savers in Australia.* Work, 2010. **36**(2): p. 181-92.
18. Ryan, K.M., et al., *Injuries and exposures among ocean safety providers: A review of workplace injuries and exposures from 2007-2012.* J Occup Environ Hyg, 2017. **14**(7): p. 534-539.
19. Bergen, C.v., et al., *Windsurfing vs kitesurfing: Injuries at the North Sea over a 2-year period.* World Journal of Orthopedics, 2016. **7**(12).
20. Dyson, R., M. Buchanan, and T. Hale, *Incidence of sports injuries in elite competitive and recreational windsurfers.* Br J Sports Med, 2006. **40**(4): p. 346-50.
21. Lundgren, L., et al., *High ankle sprain: The new elite surfing injury?* International Sport Medicine Journal, 2014. **15**: p. 7.

22. Lundgren, L.E., et al., *Comparison of impact forces, accelerations and ankle range of motion in surfing-related landing tasks.* Journal of Sports Sciences, 2015. **34**(11): p. 1051-1057.
23. Silva, B., et al., *Injuries among Portuguese kitesurfers: The most affected body regions A pilot study.* Motricidade, 2016. **11**(4).
24. Ludcke, J.A., *Modelling of Inflatable Rescue Boats (*IRB*s) in Surf Conditions to Reduce Injuries*, in *School of Mechanical, Manufacturing and Medical Engineering*. 2001, Queensland University of Technology. p. 263.
25. Ludcke, J.A., et al., *Impact data for the investigation of injuries in inflatable resuce boats (*IRB*s).* Australasian Physical and Engineering Sciences in Medicine, 2001. **24**(2): p. 7.
26. Corbett, B., M. Thompson, and R. Budd, *Board of Life saving - Minutes:* IRB *Review*. 2010. p. 1-38.
27. Reilly, T., et al., *Fitness Requirements for RNLI Beach Lifeguards to operate Rescue Watercraft and Inshore Rescue Boats*. 2004, Roya National Lifeboat Institution: University of Portsmouth. p. 1-23.
28. Reilly, T., J. Gillis, and M. Tipton, *Fitness Training Programme for RNLI Beach Lifeguards Operating Rescue Water Craft (RWC) and Inshore Rescue Boats (*IRB*)*. 2005, Institute of Biomedical & Biomolecular Sciences: University of Portsmouth. p. 1-10.
29. Scanlan, A.T. and B.J. Dascombe, *The anthropometric and performance charactersitics of high-performance junior surf life savers.* Serbian Journal of Sports Sciences, 2011. **5**(2): p. 7.

TABLES

Table 1: Characteristics of studies included in the systematic review

Study authors [reference], design, focus (quality rating *if applicable***), *Haddon's matrix injury causation area***	**Methods, participant characteristics**	**Findings**	**Author's comments and critique**
Ashton et al. (2001) [3] Case series. Foot and ankle injuries occurring in inflatable rescue boats (IRB) during surf lifesaving activities. (3) *Injury and treatment.*	• Mona Vale Hospital regional emergency department over 3-yrs analysed by injury diagnosis, mechanism, potential risk factors. • Preventative measures recommended. • 12 participants (11 male, 1 female; 11 crew members, 1 driver) 29.25 yrs, (min=14, max=52)	• 12 foot and ankle significant injuries relating to IRB usage. • 6 Lisfranc fracture dislocations of the midfoot, 4 ankle fracture variants, 1 tibial shaft fracture, 1 traumatic rupture of peroneal retinaculum leading to peroneal tendon dislocation. • 3 injuries when waves overturned IRB throwing occupants from the boat (ejected from IRB). • 4 injuries when IRB*s* landed heavily after driving over large waves (landing). • 4 injuries when IRB*s* hit by broken waves (navigating a wave). • 1 injury occurred an occupant alighted from IRB as it approached the beach at speed (exiting IRB). • 10 of 12 injuries from rider being twisted around his locked feet or from rider being catapulted from boat while feet remained fixed to floor in foot straps. • 11 of 12 injuries occurred to the crewman.	• Majority of injuries could in part be attributed to use of foot straps fixed to boat floor. • Injuries might be decreased with modifications to IRB. • Foot straps were made of rigid plastic bolted to the floor. Foot straps could be replaced with a rubber support like a recreational water ski boot. This would offer greater elasticity and 'give', allow adjustment to foot size and stance position, and have a heel support to prevent midfoot abduction. *Rubber straps have been implemented after this study.* • Front hood should be removed, and an additional hand grip added to allow the crewman greater protection against impact. • Crewmen took initial impact of the wave while having no control over boat direction. • Recommendation to remove foot straps and rely on handgrips - limited and may increase injuries occurring due to ejection from the boat or landing. • Recommendation of body harness may be too demanding, particularly to lifesavers on patrol.

Bigby et al. (2000) [4] Epidemiological retrospective survey. The incidence of inflatable rescue boat injuries in Queensland surf lifesavers. (3) *Injury and treatment.*	• Estimated and analysed serious IRB-related injuries in Queensland from 1997 to 1998 that resulted in workers compensation. • WorkCover Queensland Database IRB logbooks from SLSQ clubs to estimate user rates. • 57 surf lifesaving clubs in Queensland (20,513 members) • 101 insurance claims (37 involving IRB*s*). • Average male 21.5 (15-54 yrs); female 23.5 (15-41 yrs). • Qualitative information from questionnaire to 43 experienced surf lifesavers regarding injuries occurring in last five years.	• Of 36 injuries, 22 (61%) to right side of body, with 68% of those to lower limb (knee, leg, ankle). • Fractures/dislocations most common (9/12 lower limb fractures). • 16 injuries during patrol duties or rescues, 11 during training, 9 during competition. • Of survey questionnaire 18/21 injuries occurred to crew member. • Sea conditions most often 'medium' with average chop (16/21 injuries) and overcast weather (10/21). • Most injuries when boat proceeding out to sea (16/21). • Speed of boat was 'slow' (10/21) or 'medium' (7/21) in most cases at injury time. • Questionnaire risk factors reported: inappropriate operation (15/43), inexperience (9/43), inadequate training (6/43), faulty equipment (4/43), incorrect placement of the foot strap in IRB*s* (3/43), and lack of fitness (1/43).	• Estimated 12 volunteer surf lifesavers/1000 per seasons were injured severely enough to make a worker's compensation claim. • Estimated high IRB-related injury rate per 1000 hours due to limited time spent in IRB*s*. • Seems to be a trade-off between experience in IRB*s* and risk of injury (chronic and acute). • Predominance of right-sided lower limb fractures, occurring to crew members - suggesting a poorly braced position in front of the craft. • Australian crew member technique differs to New Zealand trained technique which may influence bracing position. • IRB design features potentially amenable may help effect modification. • Recommendation to further delineate and test in the field, combining epidemiological and biomechanical methods.
Van Bergen et al. (2016) [19] Epidemiological retrospective. Windsurfing vs kitesurfing injuries at North Sea over 2 years. (4) *Injury and treatment.*	• Analysed windsurfing and kitesurfing injuries presented at coastal hospital over September 2009 - September 2011 (Red Cross Hospital, The Netherlands) to assess epidemiology and risk factors. • Electronic Patient Data system analysed from (term search "surf" and "kite"). • Charts manually reviewed, extracting data. • Patients sent questionnaires for any information that could not be retrieved from the charts. • 57 patients (25 windsurfers, 32 kite surfers) 44 males, 13 females 30 ±11-57 yrs.	• Windsurfers had significantly higher skills level than kite surfers • Only 17% WS and 28% KS used protective gear (helmets). • 5.2 injuries per 1000 hours of WS over 2-year period. • - some minor injuries (contusions, lacerations, and ankle sprains) - lower limbs most affected - medium or severe severity in most cases (not significantly different between groups, age, skill, or use of gear). • 7.0 injuries per 1000 hours of KS over 2-year period. - some minor injuries (contusions, lacerations, and ankle sprains) - medium or severe severity in most cases (not significantly different	• Sports closely connected to the elements and therefore high level of unpredictability. • Speculated less experienced athletes sustained more severe injuries (questionable as limited number of participants, and conflicting research in other water-based sports). • Little is known about protective gear in windsurfing and kitesurfing. • Foot straps have been designed in WS for easier exit. • Recommended that better use of protective gear and WR systems offers possibilities for education and counseling. • Limitations in "text" search. • Injury rates calculated retrospectively (via patient feedback).

	• 18 windsurfers (72%) and 26 kite surfers (81%) completed questionnaire.	between groups, age, skill, or use of gear).	
Dalton et al. (2014) [8] Injury report - Case series. Serious injury summary 2013-14 season. *Injury and treatment.*	• SLSNZ PAM database and injury report forms for surf lifesavers injured while patrolling or competing in New Zealand. • October 2013 to April 2014. • 16-60+ yrs.	• Provided full season summary of serious injuries reported during 13/14 lifeguarding season and at all national sporting events. • Per capita serious injury rate reported 14 times greater in IRB nationals than any other sporting event. • During 2013/14 season 479 first aid incidents for SLS members recorded in PAM system. • Ranged from sand in eye and minor cuts requiring a plaster to incidents requiring hospitalization. • Members made up 28% of total first aid patients (1,717) treated over the season. • 15 of 479 incidents (3.0%) required a trip to hospital for treatment. • 1 (7%) incident during patrol where individual fell from moving trailer being towed back to clubhouse and dislocated shoulder. • 4 other lifesaving-related incidents (27%) – training with IRB's. • 7 (47%) incidents involved members with sport-related activities. • 1 incident was a migraine; context of 2 other incidents was not recorded.	• Provided report on serious injuries that involved SLSNZ members for clubs to assist developing their own local injury prevention strategies.
Dalton et al. (2015) [12] Case series. Serious injury summary 2014-15 season. *Injury and treatment.*	• SLSNZ PAM database and injury report forms for surf lifesavers injured while patrolling or competing in New Zealand. • October 2014 to April 2015. • 16-60+ yrs.	• Of 392 reports of members needing first aid in 2014/15 season recorded in PAM database, 48 required treatment by a doctor and 21 needed a visit to hospital. • 392 member first aid incidents made up 16.7% of total 2,342 first aids completed in the season. • This was down from 22% last season (383 out of 1,717). • Good progress in Sport (down 38%) and IRB's (down 54%).	• Provided report on serious injuries that involved SLSNZ members for clubs to assist developing their own local injury prevention strategies.

Dalton et al. (2016) [11] Case series. Serious injury summary 2015-16 season. *Injury and treatment.*	• SLSNZ PAM database and injury report forms for surf lifesavers injured while patrolling or competing in New Zealand. • October 2015 to April 2016. • 16-60+ yrs.	• Excluding national sports events and SLSNZ employees there were 265 reports of members needing first aid in 2015/16 season recorded in PAM database, 38 required treatment by a doctor and 12 needed a hospital visit. • 265 member first aid incidents made up 13.6% of total 1,939 first aids completed in season. Slightly below overall 16.7% last season (392 of 2,342).	• Provided report on serious injuries that involved SLSNZ members for clubs to assist developing their own local injury prevention strategies.
Dalton et al. (2017) [10] Case series. Serious injury summary 2016-17 season. *Injury and treatment.*	• SLSNZ PAM database and injury report forms for surf lifesavers injured while patrolling or competing in New Zealand. • October 2016 to April 2017. • 16-60+ yrs.	• Excluding national sports events and SLSNZ employees there have been 70 reports of members needing first aid in the 2016/17 season recorded in the PAM database, 24 of which have required treatment by a doctor and 13 needing a visit to hospital. The 37 member Serious First Aid incidents above made up 12.6% of the total 292 Major First Aids completed this season. This compares to 13.6% of all First Aids last season (265 out of 1,939). Minor member First Aids are not being recorded in PAM this season.	• Provided report on serious injuries that involved SLSNZ members for clubs to assist developing their own local injury prevention strategies.
Dalton et al. (2018) [9] Case series. Serious injury summary 2017-18 season. *Injury and treatment.*	• SLSNZ PAM database and injury report forms for surf lifesavers injured while patrolling or competing in New Zealand. • October 2017 to April 2018. • 16-60+ yrs.	• Excluding national sports events and SLSNZ employees there were 73 reports of members needing first aid in 2017/18 season. • 20 required treatment by a doctor and 10 needed ambulance transport to hospital. • 30 member serious first aid incidents made up 10% of total 299 major first aids completed in season. • Compared to 12% of Major First Aids last season (37 out of 308).	•
Dyson et al. (2006) [20] Retrospective questionnaire. Incidence of sports injuries in elite competitive and	• Injury incidence in windsurfing over a two-year period. • Windsurfing specific questionnaire requiring participants to list injuries and factors around how and when the injuries occurred.	• Average injury rate was 2 times greater in WX group than RB group. • 5 concussions reported in WS, only 1 in REC - none wearing helmet. • Most common injury in all groups was muscle strain (35% of all injuries).	• Importance of ensuring fast mechanism of foot strap release particularly because of fracture risk. • Unpredictable weather conditions a risk factor. • WS indicated knee and ankle ligaments may be due to stress during take-off and high forces upon landing after aerial flight.

recreational windsurfers. (3) *Injury and treatment.*	• 107 respondents (19 women). • Raceboard 31.8 ±16.6 yrs. • Wave/slalom 28.5 ±10.0 yrs. • Recreational 30.1 ±13.6 yrs.	• Respondents identified ineffective foot strap release as cause of injury in 2 cases. • Preventative measures included lumbar back support belt, helmet, wet suit boots. • Lower body - 22% of soft tissue injuries were lower back muscular strains. All groups reported recurrent and ongoing lower back injuries. • 1.5 injuries/person/year with high incidence of new and recurrent muscular strains. • Lower back muscular strain was prevalent. • Comparison of elite windsurfers revealed that participation in wave/slalom events was associated with more new and recurrent injuries, and the need for head protection. • REC indicated most ligament sprains in ankle and foot, and WS indicated knee and ankle ligaments.	• Recurrent lower back injuries were not found in other studies due to narrowed focus on more acute injuries yet made up 28% of all lower body soft tissue injuries). • Recommended use of neoprene waist and lower back support, and possible use of harness with good release.
Erby et al. (2010) [17] Cross-sectional. Trial of an injury reporting system for surf lifesavers in Australia. (3) *Injury and treatment.*	• Injury reporting form designed and piloted at National Surf Lifesaving Championship 1998/1998. • Outcome Measures: 1. Number of forms returned 2. Completeness of data recorded in each section 3. Difficulties in coding and entering data from each form section 4. Feedback from medical tent personnel about form usability. • Body region and nature of injury were coded. • 6,566 total event competitors: Open age groups, 15 years and over, master's aged 30 and over. • Sex proportions entered at carnival unknown	• Piloted an injury reporting form designed for use in Australian surf lifesaving; the need for such a form was to meet legislative requirements and was an initial step in developing an injury prevention program for volunteer surf lifesavers. • 431 injury report forms 334 injuries (77.1% total number of returned forms) - derived injury incidence was 63.9/1000 competitors 70.1% new injuries, aggravation of injury (16.9%), and recurrent (7.6%) 81.9% during competition, 9.3% during training • Most prevalent were surfboat injuries (58.5%) and then surf ski (10.2%) • Feet and toes most injured (12.1%), lower back (7.6%) • Surfboat significantly related to "collision with craft" injury	• Number of competitors in each event was not identified, therefore unable to compare injury rates across events. • Much of injury pathology lost as only first description was used in analysis (severely underestimated nature of injury). • Issues with form: years' experience missing, full description of incident not detailed, mechanisms needed to be more specified (was not free text). • Wave size and type, sea conditions, wind speed and weather conditions generally at venue maybe factors involved with injury occurrence in this environment, however, nothing to compare to.

	• 354 competitor injuries (52.5% men, 47.2% women), 26.8 ±11.66 yrs.		
Jackson et al. (2017) [16] Thesis Systematic review. Retrospective survey. Musculoskeletal injuries in California ocean lifeguards. *Injury and treatment.*	• Described musculoskeletal injuries in California ocean lifeguards. • Examined demographic risk factors. • Injuries were totaled by people reporting injuries, and total number of injuries reported (over a lifetime of lifeguarding). • Injury definition: any job-related complaint of pain or problem (stiffness, swelling, instability/giving way, or other complaints) that affected participant's ability to physically train for or perform lifeguard duties. • 1,401 members over 18 yrs sent survey: demographic, injury type and location. • 431 respondents (80% male, 20.8% female) - 32.8 ±14.3 yrs old, 12.5 ±11.9 yrs experience.	• Only 422 responded to injury question ("job-related"). • 60.7% reported injury (averaging 5.6 injuries per lifeguard). • Workers compensation filed for 19.5% of injuries. • Lower leg and ankle (15.1%), foot (15.0%), thigh/knee (11.1%) most common site. • Strains (28.6%) - ankle sprain (5.8% of total), low back strain (5.2% of total) most common type. • 6.0% of injuries required surgery, knee most common location. • Male and female similar proportions of injuries. • More experienced and older population reported higher proportion of injuries.	• No assessment of causation of injury. • No assessment of age, years of experience, or employment status at the time of injury, therefore increased injuries to experienced population may be due to an accumulation over the years of training, rather than a significant relationship.
Mitchell et al. (2013) [2] Cross-sectional. *The epidemiology of competition and training-based surf sport-related injury in Australia, 2003–2011.* (4) *Injury and treatment.*	• Competition and training-based surf sport-related injuries from surf lifesaving Australia's Surf-Guard Incident Reporting Database from 1 Jan 2003 to 20 Aug 2011. • 3,006 injury records 1,313 male, 1,230 females.	• No significant sex differences. • Individuals >35 yrs old experienced high proportion of injuries during training than younger. • Activities involving IRB*s* were most common type of activity performed for both competition and training. • Returning to shore and negotiating break were most common contributing factors.	• No injury location identified. • Not possible to decipher water vs. land injuries. • Only age ranges given. • Injury rates could not be calculated. • SLSA SafeGuard database has not be validated. • Recommended efforts to improve data capture capabilities for injuries during competitions and training.

Moran et al. (2013) [5] *Also* Moran et al. (2014) [6] Retrospective epidemiology review. Surfing and leisure injuries requiring first aid in New Zealand, 2007-2012. (4) *Injury and treatment.*	• Retrospective descriptive analysis of surfing injuries occurring at patrolled surf beaches requiring first aid by surf lifesavers in NZ. • SLSNZ database. • From 2007-2012. • Information grouped, numerically coded, tabulated according to injury site. • 8,437 incidents (68% male, 31% female) 43% between 16-30 yrs, 25% 11-15 yrs.	• Most injuries treated were lacerations/abrasions (59.2%). • More males reported bruising than females. • 74.6% left in stable condition, 15.9% referred to doctor, and 4.4% transported to hospital. • 42% in lower limbs, 31.7% in head/neck/ eyes. • Data included only surfing-related cases treated by surf lifeguards; not treated by other agencies or bystanders; nor injuries at non-patrolled beaches, nor injuries outside summer patrol season (late October through late April).	• Wanted to develop evidence-based recommendations for promotion of public safety measures. • SLSNZ database has gaps including patient information (same forms as for surf lifesaver injuries). • Limitations in database and reporting procedures may adversely affect accuracy of data collection. • Not all cases included written notes to identify the nature and cause of injury. Given notes were written mostly by nonmedical personnel, clinical accuracy of information provided cannot be assured. • Injury outcomes initially treated at beach not known. • Follow-up study to relate on-site and subsequent medical treatment of surf injuries is recommended.
Ryan et al. (2017) [18] Retrospective epidemiology - Case series. Injuries and exposures among ocean safety providers: A review of workplace injuries and exposures from 2007-2012 (3) *Injury and treatment.*	• Lifeguard injury patterns in Honolulu Ocean Safety and Lifeguard Services Division. • Determined how self-reported injury data from same division related to existing Occupational Safety Health Administration (OSHA) data and whether there was potential for under reporting of injuries. • Injury data from OSHA summary logs (2007-2012). • Survey to 185/200 active personnel (demographics, injury within last year, workers compensation details).	• 304 OSHA claims full time: 231 (75.9%; 95% CI 71.1–80.7%) part time: 45 (14.8%; 95%CI 10.8–18.8%). • OSHA: Lower extremity most injured (34.2%) and accounted for most days lost (31.9%). • 35.5% occurred during rescue, and 25% did not specify. • Back injuries resulted in 13% of full-time employees and 17.8% part time. • 52 surveys completed (28% response rate): 1.54 ±10.2 yrs as lifeguard. • 42.3% experienced workplace injury in last year, but only 14 (63.6%) filed a claim. • Back and foot were most injured (59.1%).	• Low response rate of survey. • Recall bias. • No use of IRBs by lifeguards.
Silva et al. (2016) [23] Retrospective epidemiology review Injuries among Portuguese kite surfers.	• Investigated incidence of injuries to Portuguese kite surfers to better understand associated injury mechanisms. • Questionnaire web-based - 12 months: general information, physical activity,	• 56.3% assumed use of protective equipment 53 reported injury (35 reported multiple injuries). • Superficial wounds and sprains most reported (18.5% each). • Knee and lumbar most injured (12.4% and 11.2%) - Lower body = 52.9%.	• Assumption that kite surfers with an initiation course, more yrs experience, that perform warm-up and use protective equipment have less injuries was not verified.

(4) *Injury and treatment.*	protection systems, injuries, consequences of injuries. • 87 respondents (5 female, 82 male) 34.2 ±9.1 yrs old; 4.9 ±3.2 yrs experience.	• Majority occurred while landing (n=26), maneuver (n=22), or (n=19) jump.	
Reilly et al. (2005) [28] [Thesis] Fitness training programme for RNLI beach lifeguards operating rescue WC and IRB. *Body – motor control.*	• Two training programmes developed based on previous 1RM measurements obtained during frequently preformed IRB-related tasks. • No participants included in this study.	• Training programme aimed at RNLI BLG to improve upper and lower body strength.	• Two training programmes introduced: beach-based and gym-based. • No data were collected, and the programmes were not tested for effectiveness. • No water-based activities included in the programmes.
Reilly et al. (2004) [27] [Thesis] Questionnaire, systematic review, simulation. Fitness requirements for RNLI beach lifeguards to operate rescue watercraft (RWC) and inshore rescue boats (IRB). *Body – motor control.*	• Questionnaire measurement of physiological demands of tasks. • Task simulation and replication (n=10). • External load (n=3).	• Established the most physically demanding tasks involved in operating RWC and IRB. • Determined external loads involved in working with RWC and IRB. • Participants indicated the most demanding tasks associated with IRB were: Lifting trailer to launch IRB, pulling IRB off trailer, pulling and lifting IRB, pulling and lifting trailer, dragging IRB on beach, launching IRB, boarding from water, working in surf.	• No water-based measurements were conducted.
Scanlan et al. (2011) [29] Cross-sectional. Anthropometric and performance characteristics of high-performance junior lifesavers. (4) *Body – motor control.*	• Anthropometric (stature, body mass, arm span) and performance (vertical jump height, 5m and 20m sprint times, peak velocity, flexibility, 505 agility, estimated VO2 max, chest strength, back and leg strength (IKD) characteristics. • High-performance Australian junior lifesavers. • 33 males: 13.8 ±1.5 yrs; 164.3 ±9.4 cm; 54.5 ±11.2 kg. • 30 females 13.5 ±1.6 yrs; 157.7 ±9.1 cm; 49.5 ±9.6 kg.	• Identified sex differences. • Males: greater stature, arm span, vertical jump height, VO2max, and back and leg strength. • Females: greater hamstring flexibility.	• All < 15 yrs. Growth and maturation can affect performance and anthropometric characteristics up until 18 yrs. • IKD is a poor measure of dynamic strength, which is required of most SLS tasks. • More research needed to develop standard values within the population of athletes.

Lundgren et al. (2014) [21] Case series, retrospective. High ankle sprain: The new elite surfing injury? (3) *Technique. Injury and treatment.*	• Examination performed on site, via palpation, anterior drawer test, talar tilt test, squeeze test, and external rotation test, and sent for MRI scan. • Official video used to describe injury situation. • 2D video recording (Tracker 4.80) for variables. • case 1: 19 yr male case 2: 20 yr male	• Two cases of acute ankle injuries from aerial maneuvers sustained at a professional surfing event. • Cases differed in severity. • Training should be guided to develop and evaluate and target capacity for athletes to handle compression forces and dynamic landing situations. • Training should include landing exercise and movement preparation to increase ability to absorb compression forces, and increase lower extremity strength, power and mobility in order to transfer the high energy through the lower limbs.	• Only 2D and could not accurately describe foot position at landing.
Ludcke et al. (2001) [24] Thesis [Systematic review, Case-control study (floorboard), In-Lab Assessment, In-lab recreation simulation]. Modelling of IRB*s* in surf conditions to reduce injuries. *Equipment. Technique.*	• Systematic review. • Design analysis of IRBs in Queensland. • Field tests of accelerations of IRB. • 3D simulation model.	• Identified injury causes and proposed processes that may reduce instances and severity of injury to surf lifesavers during IRB operation. • Simulated wave, loading the boats flex around a pivot point determined by the position of the hinge in the floorboard (close to where the foot strap locations usually are placed. • Accelerations felt by crew exhibited similar characteristics to road vehicle accidents. • Attributes of optimum foam thickness and density were found, and optimum crewing positions. • Observed lack of adherence to SLSA foot strap standard impeded successful epidemiological and modelling outcomes.	• Uniformity of boat setup needed to highlight influence of implementing changes to boat design. • Accelerations were measured at the floorboard on the boat, not on the crew member themselves.
Ludke et al. (2001) [25] Case series, Technical note. Impact data for investigation of injuries in IRB*s*. (2) *Equipment.*	• Custom built accelerometer and data logging system (accelerometer attached to floorboard, just behind the hinge point). • Visual analysis of waveforms to identify wave impacts.	• Identified causes of injury and proposed processes that may reduce instances and severity of injury to surf lifesavers during IRB operation - particularly accelerations experienced by crew members and IRB. • High impulse (average 23g pulse for 25ms) exerted by each wave (rather than peak acceleration) - major factor in injury causes.	• Low sampling rate. • No synchronization method between video and accelerometer. • Accelerometer was removed after each trial therefore possible error in calibration of direction. • Visual analysis of wave form not validated. • No angular velocities measured. • Noise not removed from data. • Study determined sensor thresholds.

Technique.		• 50g is adequate to capture necessary spikes in accelerations.	• Impact data analysis was performed on one-off events, where impacts associated with IRB*s* occurs repeatedly every time the boat travels over a wave.
Yorkston et al. (2005) [1] Case-control study, cross-sectional study IRB-related injuries in Queensland surf lifesavers: epidemiology - biomechanics interface. (3) *Equipment. Technique.*	• Developed epidemiological and biomechanical methodologies and measurement instruments that identify and measure the risk factors. • Questionnaire paper based. • Age, physical characteristics, training, and experience. • On-board video camera (still images of crewing technique). • 10 minutes of IRB operation. • Custom-built piezo electric force plate. • Crewman's foot straps orientated as per IRB (Arancia 380) manufacturers specifications were fixed to superior surface of force plate. • 15 Queensland surf lifesavers, 12 males.	• Described relationship between epidemiological and biomechanical factors in casual pathway of IRB-related injuries in Australian surf lifesavers. • Conceptual model of RF: Wave forces, boat forces, forces transferred at impact, physical attributes of IRB, IRB crewing techniques, training, experience, forces applied to host. • 404.5N max force for anterior left foot. • Right side measurements smaller and closer in range than left side (149.0N posterior). • Summation of forces showed left transducer registered 2 x forces as right side.	• Only measured GRF, no accelerations (no kinetic energy can be calculated). • Would have been beneficial to measure centre of mass. • Less force on left side with previous research suggested greater injuries occur to right limb. • Many participants did not use right foot strap (modification to technique). • Exact forces unknown, magnitude of forces was referenced.
Lundgren et al. (2015) [22] Lab research, Case series, Cross-sectional. Comparison of impact forces, accelerations and ankle range of motion in surfing-related landing tasks. (4) *Equipment. Technique.*	• Described impact forces, accelerations, and ankle range of motion in five different landing tasks used in training and testing for competitive surfing athletes. • Inertial measurement units (XSENS up to 18g) placed at mid-foot and mid-tibia sacrum, and T8. • Force plates. • Performed battery of 5 landing tasks. • Analysed resultant peak accelerations, vertical force (max peak). • 11 male professional surfers 24 ±6.9 yrs, 1.8 ±0.5 m, 70 ±9.0 kg.	• Moderate to high correlation (r=0.69–0.82, p≤ 0.01) between relative peak landing force 2.3-17.3 N/BW and tibial resultant peak acceleration 5.3g to 21.4g. • ICC of tibial accelerations were most satisfactory (0.63 to 0.93). • Tibial acceleration sensor placement was more reliable, and better represents vertical peak force compared to sensors at sacrum and T8. • Different kinematic landing strategies between tasks. • A reason for decreased dorsiflexion range of motion in trampoline landing condition with a board was the athlete's feet need to be in board contact during landing preparation.	• Suggested that those with less static dorsiflexion range of motion must use more of their total range to perform the landing. • Limited acceleration range for IRB comparison. • Similar potential for decreased dorsiflexion in IRB due to similar landing (board on water). • Recommendation that magnitude of load quantified in intervals, rather than exact numbers. • Limited sampling frequency (600 Hz). • Tibial inertial sensors can be applied to provide an estimation of peak impact in landing tasks. • High correlations in basic landing tasks. • The effect on kinetics of landing seemed substantial and needs

			further attention in researching board sport performance.
Inflatable Rescue Boat Training Manual. (2018). [7] *Knowledge*.	SLSNZ specific inflatable rescue boat training manual for 2018.	• Manual information includes equipment standards, crew and driver training, and operation information (fuel, communication, maritime regulations, IRB setup, basic skills and techniques for crew and driver specific, rescues, IRB closedown).	• Equipment specifications specify parts, but do not specify location of foot straps. • IRB set-up does include lifting techniques for heavier equipment (engine, pontoons, etc.). • Basic skills for crew and drivers were good, but limited information was provided, around crewing position when navigating a wave (e.g. feet placement). • Limited information regarding landing techniques was provided for landing after going over a wave (e.g. bracing for impact).
Corbett et al. (2010) [26] Technical Report. Board of Life saving - Minutes: IRB Review. *Knowledge*.	• Board meeting discussion around IRB-related training, education, culture, gear and equipment, and IRB injury data.	• Changes included: Removal of right foot strap mandatory. • Must replace all remaining foot straps with adjustable. IRB injury data needs to be improved. • Training and Education IRB Crew Certificate - Prior to any practical crew, training candidates must complete IRB theory session. - Advised that minimum hours of training be implemented but denied. - IRB crew learner guide needs clear process of how IRB crew training is to be carried out (lesson plans). - Recommended candidates must be 16 (kept it 15). • IRB driving certificate - Recommended hourly requirements but denied. • IRB training certificate - Kept standard of having to assist training one squad with a qualified mentor. - Accredited IRB trainers must attend nationally set IRB trainer workshop. • Claim: it is not the equipment, but the person in control of the boat.	• More clarification needed for reasons to deny recommended training and education changes. • What evidence to support "claim". • What evidence to support removal of right foot strap. • Was replacement of all foot straps with adjustable straps carried out by clubs? followed up by SLSNZ? • No suggestions for how IRB injury data should be improved.

Table 2: Summary of host/participant, agent/mechanism, and environment/community IRB *risk factors, the potentially modifiable risk factors, and those for which there is evidence from the scientific literature for effective injury prevention countermeasures targeted at the risk factors.*

Host/ Participant
Behaviour
Abstinence from alcohol[c]/alcohol intoxication[c]
Abstinence from drugs[c]
Readiness for risk[c]
Readiness for speed[c]
Risk taking behaviour; judgment & recklessness[c]
Use of appropriate equipment[a,b]
Lessons[a]
Ability/experience
Seasons of experience in IRB[a]
Self-reported ability (beginner intermediate, expert)[a]
Body – motor control
Physical conditioning[a]
Duration of warm-up before first ride[c]
Weight[a]
Body composition[a]
Nutrition and hydration[c]
Fitness[a]
Psychomotor skill development[c]
General health
Age[a,d]
Sex[a,d]
History of injury[a,d]
Knowledge
Knowledge about IRB safety and injury mechanisms[a]
Knowledge of safety rules[a]
Knowledge of injury prevention strategies[c]

Agent/Mechanism
Behaviour
Protector use (e.g. spine protector, knee brace)[a]
Helmet worn[a]
Other protective equipment worn[a]
Equipment ownership[c]
Seasonal checking of equipment by specialist[c]
Patrol or competition[a]
Injury and treatment
Effectiveness of treatment[a]
Severity of injury[a,d]
Protectors
Equipment design[a]
Age of equipment[c]
Storage of equipment[c]

Environment/community
Behaviour
Proximity to other participants[c]
Experience of aggressive behaviour of other participants[c]
Injury and treatment
First-aid[a]
Help-seeking behaviour[c]
Access/transport to hospital care[a]
Quality/affordability of health care[c]
Weather and terrain
Weather[a]
Wave conditions[a]
Water bans or access (barriers, signage)[a]
Competition planning[a]
Visibility (sunny/good visibility, cloudy/bad visibility)[a,d]
Temperature[c]
Protectors
Helmets[a]
Noise[c]

[a]Factors derived from literature, [b]Factors included in intervention studies, [c]Factors not yet addressed in studies, [d]Unalterable factors.