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Review

An underappreciated cause of ocean-related fatalities: A systematic review on the epidemiology, risk factors, and treatment of snorkelling-related drowning



C.L. Dunne^{a,b,c,*}, J. Madill^d, A.E. Peden^{c,e}, B. Valesco^{c,f}, John Lippmann^{g,h}, D. Szpilman^{b,c,i}, A.C. Queiroga^{c,j}

^a Department of Emergency Medicine, University of Calgary, Calgary, AB, Canada

^b Medical Committee, International Life Saving Federation, Belgium

^c International Drowning Researchers' Alliance (IDRA), Idaho, United States

^d Cumming School of Medicine, University of Calgary, Calgary, AB, Canada

^e School of Population Health, Faculty of Medicine, University of New South Wales, Sydney, NSW, Australia

^f Office of Public Health Preparedness, Maui District Health, Hawaii State Health Department, Wailuku, HI, United States

^g Australasian Diving Safety Foundation (ADSF), Australia

^h School of Public Health and Preventive Medicine, Monash University, Melbourne, Victoria, Australia

ⁱ Brazilian Lifesaving Society (SOBRASA), Barra da Tijuca, Rio de Janeiro, Brazil

^j EPI-Unit, Instituto de Saúde Pública da Universidade do Porto, Porto, Portugal

Abstract

Aim: Snorkelling is a popular aquatic activity which may result in fatal and non-fatal drowning. However, little is known about the scale of injury, factors impacting risk and strategies for prevention. This review assesses the current literature on snorkelling-related drowning with the aim of assessing available data, improving safety recommendations and reducing the global mortality burden.

Methods: A systematic review of peer-reviewed literature in English, Spanish and Portuguese language published between 1 January 1980 and 31 October 2020 was conducted using the PRISMA guidelines. CINAHL Complete, Embase, Medline (Ovid), PubMed, SafetyLit, SportDiscus and grey literature were searched to identify studies reporting the incidence of fatal and non-fatal snorkelling-related drowning, or associated risk factors, prevention strategies, treatments or casualty characteristics. Quality was assessed using the NIH Quality Assessment Tool.

Results: Forty-three studies were included (26 reporting population data, 17 case series), of which 27 (62.8%) studies reported data from Australia. Incidence was reported as about 8% of total ocean-related drownings. Case series documented 144 fatalities over 17 years. Frequent casualty characteristics include male (82.6%), pre-existing heart disease (59.4%), tourists (73%) who were inexperienced (71.0%), and lack of a buddy system (89.6%). Two at-risk profiles identified were older adult tourists with pre-existing medical conditions and local, experienced spearfishers. Twenty-two expert recommendations were developed to improve the safety of snorkellers related to individuals, tourism companies, government agencies and diving organisations.

Conclusion: Snorkelling-related drownings are not infrequent, and there are many opportunities to improve the safety of this activity based on available data.

Keywords: Drowning, Diving, Snorkelling, Risk factors, Injury, Ocean, Treatment, Epidemiology, Prevention, Intervention

* Corresponding author at: Department of Emergency Medicine, Foothills Medical Center, 1409 – 29 St NW, Calgary, AB T2N2T9, Canada.
E-mail address: cody.dunne@ucalgary.ca (C.L. Dunne).

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Introduction

Drowning is a significant cause of mortality worldwide.^{1,2} However, many published reports do not clearly describe the environment that drowning occurs in, and even fewer discuss the activity that the person was participating in prior to drowning. In particular, there is little descriptive epidemiology of ocean drowning related to snorkelling.

Snorkelling is both a recreational activity and a livelihood around the world. For example, just in the region around the Great Barrier Reef in Australia, it is estimated that 1.2 million people participate in recreational snorkelling annually.³ However, those who snorkel as a hobby only represent a portion of the individuals utilizing this diving technique. Snorkelling is also used daily around the world to earn a living and to provide food for one's family through hunting (i.e., spearfishing).⁴

Despite its prevalence as a popular activity, drowning while snorkelling is not generally reported separately in national reports; instead, snorkelling is often grouped with 'swimming' or 'other diving activities'. There are multiple reasons for this. One is that there are relatively few cases compared to other drowning categories (e.g., swimming), making it challenging for national organisations to dedicate resources to detailed examination. Additionally, the International Classification of Diseases (ICD), 10th Revision, combines ocean activities into one code, "underwater diving and snorkelling (Y93.15)."⁵ and even more generally they may be labelled as accidental drowning. This lack of independent coding is an important omission as snorkelling is both an accessible and potentially dangerous activity, often conducted with little or no oversight by those with little to no experience.

Unlike swimming, snorkelling permits even a novice swimmer to go for extended immersions and may create a false sense of security in potentially hazardous water as participants have a lifeline (i.e., breathing tube) to the surface. Whereas other diving activities such as SCUBA diving requires training courses and certification before participation, snorkelling does not.⁶ Additionally, snorkelling equipment is readily available, generally not subject to safety standards, and relatively inexpensive. Although overlapping with both swimming and diving, snorkelling-related drowning is not completely characterized by either.

This systematic review was initiated to collect and assess the current literature available on the epidemiology of snorkelling-related drownings globally, with the aim to better inform future data collection and safety recommendations to further reduce the burden of such fatal and non-fatal incidents.

Methods

A systematic review of peer-reviewed and grey literature was conducted and prospectively registered with PROSPERO (#CRD42020191244).

Systematic review framework

The PICOST (Population, Interest Area, Comparator, Outcome(s), Study Designs and Timeline) framework was used to structure the systematic review. The researchers examined the burden of unintentional, snorkelling-related drownings globally (Population & Interest Area). The primary outcome was the incidence rate of these

events in different countries. Secondary outcomes were characterization of those who drowned (i.e., demographics, level of experience, equipment used, pre-existing medical conditions, and use of the buddy system), as well as identification of risk factors, prevention strategies and treatment specific to snorkelling-related drownings.

Inclusion criteria were peer-reviewed and grey literature published from 1980 onwards which reported original data on the primary or secondary outcomes. Case series required a minimum of five cases. It was decided *a priori* that languages accepted would be English, Spanish and Portuguese. These languages were selected based on the lingual fluency of the authors.

General exclusion criteria included articles that were reviews (e.g., literature, systematic or narrative), non-technical reports (e.g., newspaper or media articles), summaries of data (or duplicate data) published elsewhere or reports of intentional drownings.

Search strategy

A search of peer-reviewed literature published between January 1, 1980 and October 31, 2020 was conducted using CINAHL Complete, Embase, Medline (Ovid), PubMed, SafetyLit and SportDiscus databases. Databases were searched to identify studies exploring fatal and non-fatal snorkel-related drownings. Combinations of MeSH terms, subject headings and keywords were used for each database. The complete search strategy is included in Appendix 1 in Supplementary material.

Google Scholar was searched using the terms "drown*" AND "snorkel*" on September 19, 2020. The results were searched manually for the first 100 pages to identify any literature that was not captured by the database searches.

Grey literature was identified via several methods. The International Life Saving Federation's (ILSF) members' websites and the Divers Alert Network (DAN) regional websites and reports were examined individually looking for reports of snorkelling-related drownings. Hand searching was also performed of accessible printed copies of DAN regional annual reports and *Diving and Hyperbaric Medicine* journal (1980–1997) which were not available online. The grey literature search was conducted during October and November 2020.

Study selection

Titles and abstracts retrieved from databases searching were screened independently by two authors (CD & JM) to identify studies that met inclusion criteria. Following this, a full-text reading was conducted to determine which studies would be included in the final analysis (CD & JM). In the case of a disagreement between authors, a third reviewer assessed the abstract/article and reached a final decision. Grey literature underwent a similar full text only screening process (CD, JM, AP & JL).

Data extraction and analysis

Data from each included study were extracted by one of four authors (CD, JM, AP & JL). A pre-designed form was used to standardize the extraction process. Data extracted included casualty demographics (age, gender, pre-existing medical conditions, swim/snorkel experience), setting characteristics (location, timing of year/day, weather, water type and conditions), activity details (recreational versus occupational, equipment used, training received, lifeguarded/

supervision status, buddy system use, alcohol or drug use) and drowning event (narrative of the events leading up to, any search or rescue attempts, resuscitative interventions, and, if relevant, the coroner's assessment and outcome).

As there was concern that different literature may use different definitions, the authors clearly defined what was accepted for the terms "snorkelling" and "drowning" *a priori*. Snorkelling was differentiated from other forms of surface diving by the type of equipment used (i.e., not connected to a portable compressed breathing gas container [SCUBA] or surface-supply apparatus [hookah diving]) and the presence of a snorkel and mask. Accepted reports could include "surface snorkellers", who swim on the surface breathing through the snorkel, or "breath-hold divers", who periodically dive underwater for extended periods but were noted to have been wearing snorkel equipment.

A fatality was included if drowning was ruled the primary cause or a contributing factor. In instances where primary pathologist reports were not available and their assessment was summarized, drowning was included as a contributing factor if (i) the pathologist specifically referred to the casualty's lung being oedematous and/or heavy, or (ii) they labelled it a drowning without further explanation. In cases where there was a delayed recovery of a casualty due to submersion, it was presumed that drowning was a contributing factor even if autopsy

revealed another primary medical cause as the submersion delayed recovery and treatment (i.e., drowning was a secondary cause). Drowning was also presumed to be a contributing factor if a body was not recovered, but the person was last seen in the water snorkelling. The exception to this was if an animal attack (e.g., shark) was suspected based on the circumstances before the drowning or disappearance. In cases where it did not explicitly list drowning as the main or contributing cause of death in the case series, two medical doctors (CD & DS) reviewed the case and determined by consensus if it was a relevant factor. Otherwise, data that were not listed in the case reports were marked as unknown and were not assumed.

Data from multiple case series were combined where possible. Chi-square testing was used to assess associations between variables. Other pre-planned subgroup analyses were adult versus paediatric, and recreational versus occupational snorkelling.

In the event that randomized or non-randomized trial data were identified, the tools recommended by the Cochrane Collaboration for risk of bias and certainty of evidence would be used.^{7,8} For case series, the National Institutes of Health (NIH) Quality Assessment Tool for Case Series Studies was selected to assess for risk of bias.⁹ Quality was assessed independently by two authors (CD & JM) then compared. In the event of a disagreement, a third author (AP) resolved the conflict.

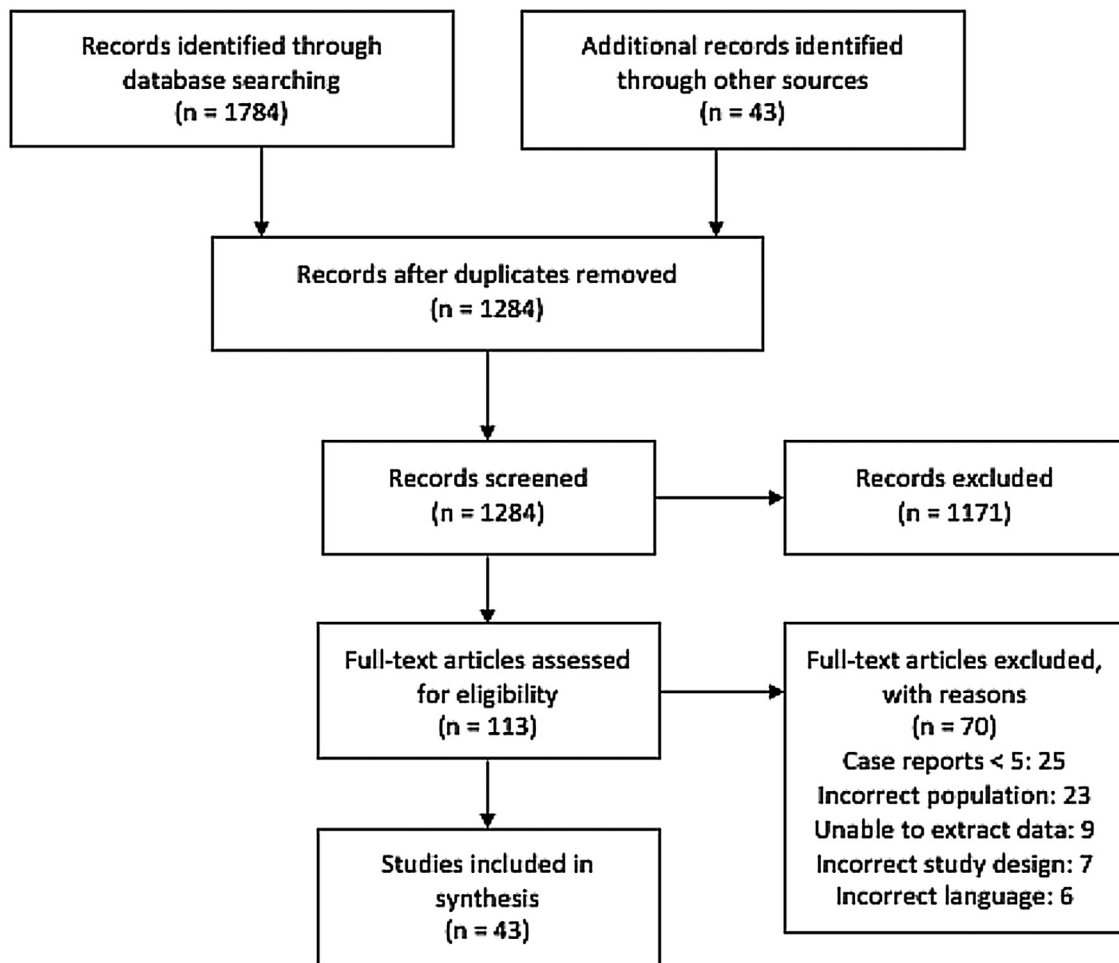


Fig. 1 – Adapted PRISMA flowchart outlining the article selection process.⁵³

Results

Search results

A total of 1284 articles were identified after deduplication. From the peer-reviewed literature databases, 1241 articles were identified, and the remaining were from inspection of grey literature references. Initial title and abstract screening yielded 113 articles, which was reduced to a final inclusion of 43 studies after full-text review.^{10–52} Fig. 1 summarizes the results of the article search and selection process in an adapted PRISMA flowchart.⁵³

Included article characteristics

Of the 43 articles that were included, 17 (39.5%) were case series, while the remainder were documents reporting on the drowning population characteristics for a country or region over a period of time. Records were found from four countries: Australia (n = 27), United States of America (n = 12), New Zealand (n = 2), and Croatia (n = 2).

Table 1 details the included case series. Together, they document 144 fatal snorkelling-related drownings over a 17-year period. No non-fatal cases were identified.

Outcome data

The incidence of fatal snorkelling-related drowning was 7.9% (95% CI = 2.7%) of all coastal drownings in Australia from 2012 to 2018.^{32–38} No other studies reported on the primary outcome (either different definitions of snorkelling-related drowning were used, or the incidence was not extractable).^{27–31,39–52} There were no incidence data for non-fatal snorkelling-related drownings. Despite limited incidence data, there was a wealth of information contained within the case series and reports regarding secondary outcomes.

The pooled characteristics of the individual cases are included in Table 2. All cases were fatal drownings. Males were

predominantly affected (82.6%). Half of the case fatalities (50.9%) were older than 50 years of age and there was only one (0.7%) paediatric casualty. Pre-existing medical conditions were common (56.1%), and of these 59.4% were cardiac-related. Respiratory conditions (7.2%) and seizure disorders (7.2%) were relatively uncommon. Although fatalities were evenly distributed between younger and older adults, pre-existing medical conditions were present much more frequently in the older age group (75.7% versus 35.1%), and this association was significant ($p < 0.00001$). The population reports echoed these results, reporting predominantly male (75.0–100%) fatalities and commonly citing pre-existing medical conditions (16.0–53.0%).^{27–52}

Two main categories of snorkelling activity were reported: tourists snorkelling as part of a vacation (73.0%), or locals snorkelling to spearfish or harvest seafood (27.0%). These groups differed significantly with regard to their prior snorkelling/swimming experience (tourist 29.0%; locals 80.0%, $p < 0.001$).

Of all drownings, 89.6% did not have a companion (buddy) present when the drowning occurred. Although 27.3% set off solo, most (72.7%) started their activity with a buddy, however, were separated prior to the incident, whether on purpose or inadvertently. The population studies also reported similar behaviour where those who drowned were frequently snorkelling alone or separate from their snorkelling partner/group (50–100%).^{27–52}

Floatation aids were used only for one in several deaths (14.6%). Further, more than half (59.7%) were snorkelling outside of a lifeguard supervised area when they drowned. For those with supervision, it was often by tour company staff designated to watch over an area where customers were swimming and snorkelling. The level of lifeguard training or experience of staff supervising was not reported.

Details of alcohol and/or drug use prior to the drowning (either from a post-mortem toxicological screen or from bystander commentary) were omitted frequently (94.5%) from the case reports. Similarly, there were often insufficient data available on other known drowning risk factors such as water conditions, or other equipment used.

Table 1 – A summary of the case series identified detailing fatal snorkelling-related drownings.^{10–26}

Primary author	Year of publication	Country studied	Number of fatal snorkelling-related drownings	Year(s) studied	Coroner reviewed	Quality assessment
Lippmann, J. et al.	2018	Australia	13	2012	Yes	Poor
Lippmann, J. et al.	2016	Australia	12	2011	Yes	Poor
Lippmann, J. et al.	2015	Australia	11	2010	Yes	Poor
Lippmann, J. et al.	2013	Australia	11	2009	Yes	Poor
Lippmann, J. et al.	2013	Australia	8	2008	Yes	Poor
Lippmann, J. et al.	2012	Australia	9	2007	Yes	Poor
Lippmann, J. et al.	2011	Australia	8	2006	Yes	Poor
Walker, D. et al.	2010	Australia	7	2005	Yes	Poor
Walker, D. et al.	2009	Australia	6	2004	Yes	Poor
Walker, D. et al.	2009	Australia	9	2003	Yes	Poor
Walker, D.	2008	Australia	7	2002	Yes	Poor
Walker, D.	2006	Australia	8	2001	Yes	Poor
Walker, D.	2006	Australia	7	2000	Yes	Poor
Walker, D.	2005	Australia	5	1999	Yes	Poor
Walker, D.	2001	Australia	5	1998	Yes	Poor
Walker, D.	2000	Australia	10	1997	Yes	Poor
Walker, D.	1999	Australia	8	1996	Yes	Poor
Total number of fatal snorkelling-related drownings identified			144			

Table 2 – Pooled characteristics of the fatal snorkelling-related drownings extracted from the case series.^{10–26}

Casualty demographics				Risk factors & interventions				
		N (#)	N (%)			N (#)	N (%)	
Gender	M	119	82.6%	Pre-existing medical condition	Yes	69	56.1%	
	F	25	17.4%		None	54	43.9%	
Age (Years)	<18	1	0.7%	Type of medical condition	Cardiac	41	59.4%	
	19–34	48	33.3%		Respiratory	5	7.2%	
	35–49	22	15.3%		Seizure Disorder	5	7.2%	
	50–64	34	23.6%		Other	22	31.9%	
	>65	39	27.1%					
Experience (All)	None	34	34.7%	Buddy system	Alone	39	27.3%	
	Some	20	20.4%		Separated from buddy	47	32.9%	
	Experienced		44		44.9%	With buddy	9	6.3%
						Separated from group	42	29.4%
Experience (Recreational)	None	32	46.4%	Supervision	With group	6	4.2%	
	Some	17	24.6%		Patrolled	58	40.3%	
	Experienced	20	29.0%		Unpatrolled	86	59.7%	
Experienced (Spearfishing)	None	2	8.0%	Floatation aid used	Yes	21	14.6%	
	Some	3	12.0%		No	75	52.1%	
	Experienced	20	80.0%		Unknown	48	33.3%	
Tourism	Local	34	27.0%	Resuscitative interventions	BLS or ALS	94	65.3%	
	Tourist	92	73.0%		Unknown or no body	50	34.7%	
Activity	Recreational snorkelling	112	77.8%					
	Spearfishing or Hunting	28	19.4%					
	Other	4	2.8%					

ALS = advanced life support; BLS = basic life support.

¹Not all categories may add up to the total cases, in the event data were not reported.

Basic life support (BLS) and/or advanced life support (ALS) was initiated in 65.3% cases where the body was found. Data were limited on the exact interventions employed by rescuers. No studies evaluated the use of prevention strategies at reducing the burden of snorkelling-related fatalities.

Quality assessment

No trials were identified to perform a certainty of evidence assessment for the primary outcome. The case series were evaluated for risk of bias using the NIH Quality Assessment Tool.¹⁷ The results of this assessment are presented in Table 1. All case series were evaluated as having poor quality (downgraded for unclear population description, inconsistent outcome reporting and for two studies not clearly stating the case series' objective). A breakdown of the individual components of the assessment tool can be found in Appendix 2 in Supplementary material.

Discussion

From the identified studies, it is evident that snorkelling is not a trivial mechanism of injury. This review has shed light on populations at risk of snorkelling-related drowning, and with improved data collection the evidence for this will strengthen.

At-risk populations and risk factors

Two high-risk populations were identified. The first were older adult tourists with pre-existing medical conditions snorkelling in the open ocean. The second were experienced locals who were snorkelling to harvest seafood.^{10–26} Amongst these two groups, different risk factors were demonstrated by the data.

Pre-existing medical conditions

The older adult population frequently had a pre-existing medical condition (75.7%) with cardiac conditions being the most common. Lippmann examined all snorkelling fatalities (i.e., not just drownings) in Australia and found similar results. They also noted that 65% of those fatalities were overweight or obese.⁵⁴ Ocean snorkelling results in a considerable strain on the body, and those with heart disease, whether known or occult, are at an increased risk of cardiac arrhythmias, myocardial injury, immersion pulmonary edema and subsequent death during these activities.^{54–58} Furthermore, when an event occurs in the water it may go unnoticed for longer, delaying intervention. Surprisingly, both respiratory and seizure disorders were not commonly attributed as being contributory, although implicated in some cases. For seizure disorders, this may in part due to public education campaigns and messaging to physicians that this diagnosis is a relative contraindication to underwater diving.⁶¹

A common risk mitigation strategy was a medical questionnaire that snorkellers listed their medical history and medications.^{14–16,22} While this strategy is recommended by the authors, it is acknowledged that it is not perfect. Cases were reported where casualties were advised to change their responses, told to snorkel instead of SCUBA due to medical history, or who purposely left out their medical issues in order to participate.^{14,22}

To improve the efficacy of this strategy, organisations need to create guidelines around common diseases where individuals are not eligible to participate or require enhanced supervision for snorkelling tours or to rent equipment. Partnerships with local medical professionals to develop these standards have been recommended and are highly encouraged.^{25,59,60} Medical oversight organisations (e.g. South Pacific Underwater Medicine Society, Undersea and Hyperbaric Medical Society) or regional governments leading this strategy would be beneficial. Queensland, an Australian state bordering the Great Barrier Reef, is an example of a region that has implementation legislation like this and created an accompanying code of practice.^{59,60}

If a health concern is identified but not deemed sufficient to elicit refusal, risk mitigation should be implemented by means of closer supervision. This can be achieved through an identification marking on the individual's snorkel to clearly indicate the need for closer observation, and/or providing a staff member to accompany them, and/or by mandating the use of a suitable floatation aid.⁶⁰ This technique can also be used for other concerns that may put a participant at moderate risk, but not high enough to refuse participation (e.g., inadequate swim or snorkel experience).

The decision to refuse someone access due to a medical condition is also complicated by the commercial pressures of the industry, where a refused participant is lost income for the owner, and likely the recruiter as well. To counter the financial incentives, regions like Queensland are setting the safety standard by implementing regulations that fine companies providing snorkelling services which do not meet minimum safety standards.⁶⁰

Educational strategies are needed to target solitary divers, tour operators and participants. One option is to inform them of the physical intensity of ocean snorkelling, the physiological changes of immersion and its effects of the heart, and the resulting injury that can occur to allow them to make informed safety decisions. In the case where refusal or enhanced supervision is required, it should always be accompanied by education around why the combination of health concerns and snorkelling is potentially dangerous.

Lack of snorkelling partner

The buddy system is a well-recognized safety system where two or more individuals perform an activity together, so they can monitor and quickly recognize if the other is in distress. The authors recommend universal use of the buddy system when snorkelling, regardless of level of experience. Experienced locals began snorkelling alone more often, however, both at-risk groups almost always (89.5%) were alone (i.e., separated from group/buddy) before the drowning occurred.

Deaths frequently occurred in individuals within groups on a tour. Being in a group can provide a false sense of security. If no one is actively observing, it is easy for a sudden and often silent loss of consciousness and subsequent submersion to go unnoticed. Snorkellers should have a partner who is not only swimming with them but is also aware of where they are at all times and should be in each other's line of sight at all times. The "one-up-one-down" system should be used when breath-hold diving is conducted. Loss of a buddy

should be the trigger for notifying responders nearby and starting an immediate search.

Language barrier

Another trend emerging from the recreational drowning profile was the issue of language barriers. Resorts and tours attract international travellers, who may not speak the native language. Language barriers interfere with two safety interventions — the medical questionnaire/liability waiver and any instructions or training provided by the tour operators. Multiple cases discussed how the casualty's companion noted afterwards that they did not comprehend the information being provided.^{12–14,22,23,26} The authors recommend that recreational organisations hosting tours or renting equipment should have a process in place (i.e., spoken, written, diagrammatic, or electronic) to translate safety information to non-native speakers prior to participation.

Professional supervision

A considerable number of recreational cases occurred under the supervision of a staff member responsible for watching participants (40.1%).^{10–26} Their level training was unknown and likely varied between organisations. Supervising a snorkeller poses unique difficulties as it involves extended periods with the face submerged and waves can lead to the perception that the snorkeller is still actively swimming and can contribute to a slowed response. Additionally, several cases reported those employees were assigned other tasks at the same time and drowning occurred while they were distracted (e.g., preparing equipment, answering questions).²² The authors support the recommendations that organisations offering snorkelling tours or rental equipment should provide a lifeguarded area where patrons can participate with trained individuals solely responsible for the supervision of participants, and with adequate breaks. Of note, the lifeguard does not replace the need for a buddy system. The lifeguard will be useful in the case of an emergency to assist with response and resuscitation, in addition to supervision duties.

Need for improved data collection

Data gaps were a common trend in the literature. It is likely that this is due to constraints in how information is obtained. Australia benefits from having a National Coronial Information System in place which can be queried for all relevant deaths. However, details are limited to what is reported at the time of the event and this varies between investigators and jurisdictions.⁶² Other countries have systems with varying degrees of reliability and timeliness, further limiting the process.⁶³ This is a barrier to accurate analysis of the problem, especially for a subsection of drowning incidents like snorkelling.

Reporting drownings

The authors support the implementation of a drowning fatality database in countries where there is none. Furthermore, using an accepted template will ensure important details like established risk factors for water-related injuries are included. Although designed for resuscitation cases, the Utstein-style Recommend Guidelines for Uniform Reporting of Data from Drowning-Related Resuscitation could act as an initial guide to ensure data collectors and coroners are documenting drowning relevant details.⁶⁴ Another potential template is the DAN Incident Reporting System.⁶⁵ Although the public can submit these reports, recreational tourists may not be aware of the tool. An innovative solution to make them more publicly accessible

would be to label a QR code linked to the reporting form onto rental fins. This may encourage participants who experience injuries and non-fatal drownings to submit their data independently. Ultimately, standardization in reporting methodology will permit comparison between reports and true analysis of the events surrounding the fatalities.⁶⁶

Non-fatal drowning data

Like other areas of drowning research, reports describing snorkelling-related events capture minimal, if any, data on the burden of non-fatal drowning. The burden of this injury mechanism is therefore grossly underestimated. Other research has estimated the rate of fatal to non-fatal drowning incidence to be between 1:2.71–1:24.4, although this varies with age and location.^{67,68} Regardless, it is well recognized that there is a significant underreporting of these events, despite the potential for long-term injury following a non-fatal drowning. Without data, risk factors, prevention strategies and resuscitative interventions cannot be assessed to improve casualty outcome. The authors recommend that where possible snorkelling-related drowning databases collect fatal and non-fatal events in the same manner and report both publicly.

Other required data

There are other risk factors that may increase a snorkeller's likelihood of drowning. These includes alcohol or drug use, equipment used, water conditions, socio-economic status of the casualty and safety policies of the tour organisations.⁶⁹ However, data on these are limited or absent. An example of why this data is needed is that there have been an increasing number of incidents involving persons wearing full-face snorkelling equipment, which has re-emerged over more recent years. Concerns have been raised about the potential for such devices to retain exhaled carbon dioxide and so affect breathing and consciousness.^{70–72} This question was not able to be answered in this review due to insufficient data on the type of snorkelling equipment.

Furthermore, without non-fatal data, assessment of rescue and resuscitative interventions is limited. Although an Australian study indicated that delays and inadequacies in rescue and resuscitative efforts were common, data collected by onsite investigators were often not detailed enough to effectively examine use of particular rescue strategies (e.g., rescue boat, or search parties), resuscitative interventions (e.g., basic life support, advanced life support, or

Table 3 – Expert recommendations to improve safety of snorkellers.

Theme	Expert recommendations
Data collection	<ul style="list-style-type: none"> • Implementation of a drowning fatality database in all countries • Use of a standardized case report structure in databases, ideally with drowning-specific components • Databases include data on both fatal and non-fatal snorkelling-related drownings • Snorkelling-related drownings be reported publicly on a regular basis as its own separate category
Risk factors	<ul style="list-style-type: none"> • Urgent implementation of educational strategies highlighting the physiological changes and physical challenges of snorkelling and higher risk of injury for certain health conditions • Refrain from the use of alcohol or drugs before or during snorkelling^a • Universal use of close-contact buddy system^b • Floatation aids be utilized by any first-time or inexperienced snorkellers • Refrain from hyperventilation before breath-hold diving^a
Recreational snorkellers	<ul style="list-style-type: none"> • Screen individuals using a medical questionnaire prior to participation in a snorkelling trip or rental of equipment and have standards regarding when to decline participation • Provide safety information and training to participants in their fluent language (e.g., by spoken, written, diagrammatic or electronic means) • Implement enhanced supervision strategies for those identified as moderate risk but participation still acceptable
Spearfishers	<ul style="list-style-type: none"> • Implement legislation/regulations by government, in regions where snorkelling is prevalent, that outline safety standards and set financial penalties for breaches • Mandate floatation aids for all trips and equipment rentals unless snorkellers demonstrate competency • Check rescue and resuscitation equipment and repair/replace as needed at regular intervals^a
skills	<ul style="list-style-type: none"> • For breath-holding dives, use the "one-up-one-down" system • Where possible, it would be beneficial for regular snorkellers to have basic aquatic rescue, CPR and first aid
Rescue and resuscitation	<ul style="list-style-type: none"> • Discuss with inexperienced and first-time recreational snorkellers how to act if in distress, and how to communicate with their buddy and company staff • Provide a lifeguarded area with adequate staff with suitable training in site supervision who are using their services or equipment • Train staff to recognize people in aquatic distress and safe response techniques^a • Assure staff is proficient in CPR and its variations in circumstances such as drowning^a • Have a contingency plan for hospital evacuation in case of an emergency to allow for rapid post-resuscitation care

CPR - cardiopulmonary resuscitation.

^a Expert opinion where evidence from the systematic review was inconclusive.

^b Budd Buddy system - safety system where two or more individuals perform an activity together, so they can monitor and quickly recognize if the other is in distress.

automated external defibrillator [AED]) or time factors (e.g., time to casualty recognition, submersion time, time to reach casualty, or time for an intervention to be initiated).⁷³ The authors have included in Table 3, expert consensus recommendations relevant to these other topics based on the limited data reported and their experience in other areas of drowning research and prevention. As the literature on snorkelling-related events improves, these may be strengthened or refined.

Recommendations

The authors recommend several interventions with the aim of reducing snorkelling-related drownings globally. These are summarized in Table 3. The recommendations identified with an asterisk represent those where insufficient data was available to draw conclusions from the systematic review but are based on the authors' expertise in other areas of drowning prevention. These recommendations should prompt discussion amongst industry and experts to further evaluate their implementation and effectiveness.

Limitations

Few countries report snorkelling as its own category making characterization of the snorkelling population and establishment of a true global burden currently impossible. When reported, recreational snorkellers and spearfishers snorkelling are usually combined, however, these profiles are inherently different. Further, data from recreational snorkellers are largely from organized tours, it is likely that individual snorkellers are grouped with other drowning categories (i.e., swimming). Studies that do report data on snorkelling-related cases rely on hospital, police and coroner data which do not follow standardized reporting templates and normally only report fatal events. Data are predominantly from two regions which affects the generalization of these recommendations. Future work will involve investigation of other regions' drowning databases to improve applicability. Finally, one author (JL) also authored several included articles, however, the author joined the team only after identification/assessment of their own articles.

Conclusion

Snorkelling is an underreported, yet still significant, cause of ocean drownings. Two at-risk profiles for snorkelling-related drownings have been identified from these data – older adult tourists with pre-existing medical conditions and experienced snorkellers spearfishing locally – and a number of recommendations to improve the safety of snorkellers and future data collections efforts have been made.

Disclaimer

The views expressed in this article are that of the authors and are not an official position of the organizations we are affiliated with.

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Conflicts of interest

None.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.resplu.2021.100103>.

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