

Injuries, Ill-Health and Fatalities in White Water Rafting and White Water Paddling

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Abstract

White water (WW) activities such as paddling (canoeing and kayaking) and rafting are popular sports for recreational and professional participants. An increase in participation has been seen worldwide. However, these activities come with a risk of injury and even death if not conducted safely. A review was conducted to identify the types of injuries and ill-health that occur as a result of these activities. Injury and fatality rates were assessed to establish the risk attributed to these activities. Web of Science, PubMed, Ergonomics Abstracts and PsycINFO databases were searched and a total of 16 published articles were identified and reviewed. The shoulders and back were the most vulnerable sites for injury in WW paddling. Injuries to the face and lower limbs were most common in WW rafters. However, injury rates are low and estimates are discussed. Due to different methods used across the studies, the reported injury rates are not comparable. This review identified three illnesses incurred through WW activities. There may be more but these are not currently reported in the literature. A relative paucity of studies regarding injuries and fatalities in WW activities was identified. Directions for future research are suggested and discussed.

1 Introduction

Outdoor activities, mostly land and water based, have been used for recreational, educational, skill development and therapeutic purposes [1]. In the UK, it was estimated that between 10 and 15 million people participate in outdoor activities a year [1]. In 2009, between 60,500 and 88,000 employees worked within the outdoor industry sector to facilitate increasing participation rates [1]. Outdoor activities are also popular worldwide. In the US, almost half of the population have participated in some form of outdoor activity [2]. Similarly, 64% of New Zealand adults was estimated to have participated in at least one outdoor activity in 2008 [3]. Adventure activities, such as white water (WW) canoeing, kayaking and rafting have shown to be especially popular [2–4]. Although popular, outdoor activities do carry a risk of injury or, in rare cases, death [5, 6].

WW canoeing and kayaking, known as the umbrella term ‘WW paddling’, involves the use of a small craft to negotiate WW rivers. Canoes are knelt in and the paddler uses a single-ended paddle. Kayakers sit in their craft and use a double-ended paddle. WW rafting is an activity where (usually) between four and eight individuals use a single inflatable craft to negotiate a river. Individuals sit side by side and use a single-bladed paddle to propel and steer the craft. This is both a commercial, recreational activity supplied by providers, as well as a competitive sport worldwide [7]. WW rivers are defined by water hydraulics formed by water falling over an uneven river bed [8]. Rivers are graded, ranging from I to VI (Table 1), depending on the rate of fall of the water, the volume of water and the nature of the river bed [8]. Higher grades indicate more dangerous rivers that are more technical to negotiate and/or have larger volumes of water [8].

In the UK, in 2010, over 2.75 million adults participated at least once in outdoor water sports [4]. Canoeing was the most popular, with over 1 million individuals participating [4]. Almost 148,000 individuals paddle at least once a month in the UK [9]; however, these figures do not differentiate between WW paddling and flat-water paddling. Similar rates are reported elsewhere. In New Zealand, for example, canoeing was the 16th most popular activity compared with all outdoor activities [3]. In the US, data on WW activities showed that, in 2010, over 1.8 million people participated in WW kayaking, an increase of almost half a million from the previous year [2], and an increase of over 100,000 participants in WW rafting was seen between 2009 and 2010, totalling almost 4.5 million participants [2].

However, WW paddling and rafting are associated with acute and chronic injuries [5, 6]. Acute injuries are incidents of pain that occur rapidly due to a specific event or trauma. Chronic injuries are defined as pain that develops over a period of time, is persisting and long lasting and is recurrent. Injuries can occur at any site of the body, with the upper body being most at risk [10, 11]. Overuse injuries that occur for prolonged periods of time can lead to more permanent issues [12]. In addition to injuries and fatalities, acute and chronic illnesses are also associated with WW activities, such as external auditory canal exostoses (EACE; also known as surfer's ear) [13] and gastrointestinal illnesses [14, 15].

With an increase in participants in many countries worldwide, it can be anticipated that there could be a proportional increase in the occurrence of injuries and potential illnesses. Fiore [6] highlights that research examining injuries within WW activities has been relatively neglected, and there is a specific lack of prospective studies assessing true injury and fatality rates.

This study reviews the types of injuries experienced in WW activities and describes details of fatalities that have occurred in the participation of these activities worldwide. Specifically, the frequency of such injuries and fatalities are examined and the methods used to report these estimates. Data from articles were synthesized to identify patterns in the literature in order to understand what is currently known and due to the limited research in this area, this review will establish a foundation of knowledge for research to be built upon.

2 Literature Search Methodology

A literature review was conducted to identify articles, from any country, on injuries and fatalities related to WW paddling and rafting published since 1990. The inclusion criteria were studies that reported any type of injuries, ranging from minor (e.g. contusions) to severe (e.g. dislocations), which required professional medical attention and fatalities that were a result of the WW activities stated. All levels of ability were examined, ranging from occasional and novice participants to qualified experts and professional competitors. Patterns in the causes of injuries and fatalities sustained were reviewed, as well as the frequency of occurrence.

The databases searched were Web of Science, PubMed, Ergonomics Abstracts and PsycINFO and, for the purpose of this review, focused on injuries, ill health and fatalities. The following terms were used both independently and combined: 'white water canoe*', 'white water kayak*', 'white water raft*', 'white water injury', 'white water morbidity', 'white water mortality', 'white water injury rates', 'white water fatality rates', 'white water acute', 'white water chronic', 'white water illness' and 'white water disease'. The term 'white water' was utilized to eliminate injuries associated with non-WW paddling and rafting. In addition to searching these databases, the references of identified journals were utilized to expand the search.

3 Findings

A total of 16 published articles were identified that met the inclusion criteria. Articles were identified from five countries; eight from the US, four from New Zealand, two from the UK, one from Ireland and one from Japan. Various methods of data collection were reported. Surveys were used in seven studies [10, 12–14, 16–18], provider records were used in three studies [19–21], hospital discharge data were used in a further two studies [22, 23], and observation [11], telephone interview [15], tourist compensation claim data [24] and kinematic data [25] were identified in single articles. Samples ranged between 54 and 473 participants of which between 53.5% and 89% were male.

The different types of injuries sustained through WW activities are summarized in Table 2.

It has been reported that the participants' ability is associated with the type of injury sustained. Fiore and Houston [16], reported that novices, defined as those competent on grade I and II rivers, sustain more acute impact-related injuries, such as abrasions, lacerations, sprains, strains and fractures. Expert paddlers, on the other hand, defined as individuals who are competent on grade V and VI rivers, sustain more chronic overuse injuries, such as tendonitis [16]. Acute and chronic injuries and injury rates have been examined in WW paddling and rafting separately. No gender differences have been observed in any category, therefore all results apply to both males and females.

3.1 Injuries

3.1.1 White Water (WW) Paddling

A total of five papers were identified that discussed acute injuries associated with WW paddling [10–12, 16, 18]. The most frequent injuries reported were lacerations, sprains/strains, fractures and dislocations [10–12, 16, 18] and the majority of injuries were reported to have occurred whilst paddlers were in their boats [16]. Most lower limb injuries occur when paddlers are ‘swimming’ after capsizing or during the hike to and from river access points [11, 16, 18]. Novice paddlers reported more lower limb injuries because they capsize more frequently [16]. Acute injuries that occurred tended to require medical attention; however, they were short term and recovery was usually complete [16].

Chronic injuries associated with WW paddling were discussed in five identified papers [10, 12, 16, 18, 25]. These papers used either a survey [10, 16, 18] or a physical examination [12, 25] to collect data on chronic injuries. The most frequently reported chronic injury was tendonitis that developed through overuse [10, 16, 18]. This was mostly observed in expert WW paddlers who frequently paddled [16, 18] and was more common in professional competitors [10]. Kameyama et al. [12] identified that multiple chronic injuries can result in deformation of the joints if not treated correctly. Deformation is an extreme example of chronic injuries. This specifically occurred in the shoulder joint, a vulnerable area of high stress when paddling. Wassinger et al. [25] also highlighted that technique could contribute to chronic injuries in the shoulders. Poor technique could contribute to uneven movement in the scapula, creating a risk of tissue damage in the shoulder due to the unnatural movement.

3.1.2 WW Rafting

A total of three papers were identified that discussed acute injuries associated with WW rafting [11, 20, 22]. The most common types of injury experienced by commercial WW raft users were abrasions, lacerations, sprains, strains and fractures [11, 20, 22]. Data collected for these studies were collected from observation [11], WW rafting providers’ records [20] or hospital discharge records [22].

The face and lower body limbs were reported to be the most common sites of injury and included lacerations, sprains, strains, fractures, contusions, dislocations and nonfatal submersion. [20, 22] All of the injuries reported in these two studies required medical attention. This was due to the parameters of the data. In all three papers, collision trauma was the most reported cause of injury. Unsurprisingly, this often occurred as a result of colliding with obstacles on the riverbed, e.g. rocks, when the participant was 'swimming' (i.e. fell out of the raft). Collisions with another raft members' equipment, e.g. a paddle, was the other common form of collision trauma reported.

Only one paper was identified that discussed chronic injuries associated with WW rafting [17]. Jackson and Verscheure [17] examined the occupational health of WW raft guides; specifically, lower back pain. They reported that chronic back pain was experienced by some WW rafting guides and that working practices associated with this injury were predominantly land based, with the loading and unloading of equipment and lifting of rafts for storing in stacks being the highest predictors of back pain. Jackson and Verscheure [17] also speculated that this could be due to the technique used. The daily routine of a raft guide requires them to lift and throw a raft in a manner that requires a rapid twisting motion of the torso, which can be harmful if it is regularly repeated. However, back pain was reported to be short lived and rarely resulted in absenteeism.

3.1.3 Injury Rates

Injury rates are summarized in Table 3. A total of four papers were identified reporting injury rates in WW paddling [10, 12, 18, 19]. In-house injury data was used in one study [19] and the remainder utilized survey data to calculate injury rates [10, 12, 18]. All studies calculated the injury rates by dividing the number of injuries reported by the unit of measurement. However, injury rates were reported using three different units of measurement; injuries per 1,000 participant hours [19], injuries per participant [12, 18] and injuries per year [10]. For example, in New Zealand, an injury rate of 0.014 per 1,000 participant hours was observed [19]. In the US, 677 injuries were observed in 388 participants, creating a rate of 2.1 injuries per participant in recreational paddlers [18]. This was more than triple the 0.69 injuries per participant reported in Japanese paddlers (n = 288) [12]. The studies that reported injuries per participant did not provide a timescale therefore an accurate

estimate cannot be calculated; however, one study, [10] which examined Olympic paddlers, reported 0.46 injuries per year (n = 57).

A total of four papers were identified as reporting injury rates in WW rafting [17, 19, 20, 22]. WW rafting provider records [19, 20], hospital data [22] and a survey [17] were the methods of data collection. Commercial WW rafting provider records in the US indicate an injury rate of 0.26 per 1,000 participants (26.3 per 100,000 participants) [20]. Provider records in New Zealand report an injury rate of 0.54 per participant 1,000 hours [19] and hospital records in New Zealand suggest that 1.04–1.81 injuries occur in every 100,000 participants [22]. The hospital record data suggests that very few injuries require hospital treatment. Although acute injury rates were predominately reported from record data, one study examined the prevalence of chronic back pain [17]. Jackson and Verscheure [17] reported a prevalence of back pain among WW raft guides in the US that was similar to the general population. This suggests that raft guides are at no additional risk of developing back pain compared with the general population.

3.2 Illness

In addition to injuries, WW users are at risk of contracting illnesses related to water activities (Table 2). A total of three papers were identified directly examining ill health in WW paddlers [13–15]. Of these, two papers examined acute illness induced by ingesting contaminated water [14, 15]. The remaining study examined chronic illness as a result of repeat exposure to cold water [13].

Lee et al. [14] assessed the relationship between water quality and participant health. Samples of water were collected and examined on an hourly basis, and then analysed alongside questionnaire data that was collected from users in the UK who participated on test days (n = 473) [14]. Ingesting river water whilst bacteria levels were high was the strongest predictor of ill-health. Frequent users of the WW facility reported fewer cases of illness than infrequent users. Boland et al. [15] explored an outbreak of leptospirosis following a canoeing competition in Ireland. They conducted telephone interviews with 62 of the competitors and a total of 18 participants reported symptoms of gastrointestinal illness following the competition; of these, six cases of leptospirosis were identified. Similar to Lee et al [14], ingesting contaminated water was the highest reported predictor of contracting the illness.

EACE is a chronic illness associated with WW kayaking and its presence was assessed using a survey and medical examination [13]. Over two-thirds of the kayakers (n = 92) in this study displayed symptoms of EACE, this was compared with 1.7% of a rock climber control group (n = 65) [13]. EACE is associated with the ear canal being exposed to cold water over a number of years and symptoms were observed in 90.6% of kayakers who had more than 10 years of experience. Only these kayakers, who had paddled for a period of 10 years or more, presented with severe symptoms of EACE (canal obstructed >67%). It was suggested that ear plugs may benefit paddlers, albeit at the cost of impaired hearing whilst in use [13].

3.3 Fatalities

Table 4 summarizes four identified papers that reported fatalities in WW paddling and rafting. All data referring to fatality rates in WW activities have been generated from the US [21] and New Zealand [17, 22, 23]. Two papers reported comprehensive rates (per 100,000 participants per annum) for WW paddling [21] and WW rafting [22] and the other two papers only reported the number of deaths that occurred, with no additional contextual information to allow for fatality rates to be calculated [17, 23].

In WW rafting, drowning and submersion accounted for 94% of fatalities [22]. Other fatalities occurred as a result of an accident to the water craft or an “unspecified fall in water transport” [22]. Fatalities seem rare, hospital data in New Zealand reported a rate of 0.16–0.27 per 100,000 participants per annum in WW rafters [22]. In the US, managed river access facility data were used to calculate fatality rates for WW paddlers and a rate of 2.9 fatalities per 100,000 participants per annum was reported [21]. Details of how the fatalities occurred in WW paddlers were not included.

Although it has been reported that more fatalities occurred in WW rafting [23, 24], differences in participation numbers could also explain the observed differences in the fatality rates.

4 Discussion

This review identified a total of 16 published articles. The main results identified through the reviewed papers were that injuries are most likely to be sustained in the upper body. Expert, particularly competitive WW users, are more at risk of sustaining

chronic injuries than novices who occasionally partake in the activities. The injury rates for recreational participants appear to be relatively low, around 4.5 per 1,000 participant days for WW paddling [18] and 26.3 per 100,000 participants in WW rafting [20]. It is important to be cautious when considering the accuracy of these rates for two reasons: first, sample sizes and methods utilized to collect data were different, meaning that injury rates, risks to health and fatality rates could not be directly compared; second, the definitions of the term 'injury' vary between studies. Schoen and Stano [18] allowed for selfreporting of injuries in a survey. This could lead to overreporting, particularly when comparing these data with injuries that required medical attention and were recorded officially by providers [20]. All WW rafting injuries were defined as requiring medical attention, therefore any injury that was perceived as not requiring medical attention were excluded from these rates. This could have occurred if the injury was not considered severe enough to report. Cultural and/or environmental differences may further influence this decision process.

This review suggests that acute injuries are often associated with hospitalizations and medical treatment [18, 22]. However, chronic injuries, such as joint distortions, can be just as severe even if they occur less frequently [12]. The only interventions that were identified in this review to reduce chronic injuries were balanced training to avoid overusing specific muscle and joint areas and adequate rest [12]. Nonetheless, the extent to which guidelines are adhered to currently remains unknown.

The review also identified that illness among WW users is most likely to occur following a flood where contaminants may be present in the water [14, 15]. Improved hygiene awareness may be beneficial in reducing an illness contracted in this way. Although governing bodies such as the British Canoe Union provide information regarding illness and disease associated with WW activities, this information is not always accessed by WW users [26]. However, the report by Philipp et al. is now dated and a more recent examination of the impact of health-related information, advice and guidelines for the prevention of illness in WW activities may be beneficial.

Weiss [11] suggested that appropriate equipment and correct techniques can prevent injuries, particularly among novices. For example, a correct paddling technique can help prevent a capsizing incident and thus avoid potential injury or fatality. Most WW rafting injuries arise from a collision. Paddlers and rafters can collide with other users, their water craft, equipment or obstacles in the water [11, 20, 22]. Whisman and Hollenhorst [20] suggest a number of preventative measures to

reduce injury prevention. These include faceguards and a limited number of users per raft [20] In addition, Cooper et al. [13] suggest the use of ear plugs to protect against the development of EACE. The extent to which personal protective equipment is effective in preventing injuries or ill-health to WW users has not been empirically tested.

Unsurprisingly, in this review, drowning was reported as the most common cause of death in WW activity users. Lower fatality rates were reported for rafting as opposed to paddling. One explanation might be that WW rafting is a commercially organized activity led by a professional guide, whereas WW paddling is a recreational activity that relies on an individual's own ability without professional guidance. In addition, WW paddlers have lower volume boats compared with rafts, so are therefore more likely to become submerged, particularly on higher-grade rivers where the water is more turbulent.

The articles reviewed here utilized various methods to assess injury types, including surveys, record data and medical examinations. Surveys are a good technique to collect data from a larger sample; however, there can be inconsistencies with interpretations of injury. For example, muscle ache could be interpreted as a strain by some and fatigue by others. Furthermore, the retrospective nature of data collection may mean that some injuries are not recalled or are recalled inadequately. Record data may be more accurate, as it is collected at the time of injury or shortly afterwards. There may also be medical assessments that inform these records. However, medical assessments are limited to those whose injuries require treatment. Less serious injuries will not be recorded. Nonetheless, a number of studies have conducted medical examinations to identify and assess injuries among WW paddlers who do not necessarily report injury [12, 13]. Such studies provide a more objective assessment. To date, there is no comprehensive way of recording injuries sustained among WW users. Utilizing a mixture of these methods may help to build a more comprehensive understanding of the injuries experienced. Comparing survey data to record data may provide insight into the types of injuries that are perceived as requiring medical intervention.

None of the articles distinguished between natural rivers and 'manmade' river facilities. A comparison examining the injuries sustained on a natural river compared with 'man-made' facilities may reveal differences in injury types. To our knowledge, this is an issue that has not been addressed in the literature. There are unlikely to be

rocks in a 'manmade' facility and this is an important issue that needs to be considered. In addition, personality factors have not been investigated in previous studies and may be a predictor of reporting behaviour and/or risk taking.

Adventure tourism has grown as an industry in New Zealand, the US, in Europe and elsewhere worldwide. It may be that as participant rates increase [2–4], injury rates will change in line with this increase. Therefore, much more attention needs to be paid to ensure these activities are as safe as possible for all those who participate.

5 Conclusion

WW adventure activities are developing with increasing numbers of participants each year [2]. The upper body is the most prone site for injuries, which can be either acute, such as abrasions, or chronic, such as back pain. Novice paddlers and commercial WW rafters appear to obtain more abrasions and impact injuries from falling out of their boat or craft. Chronic injuries are more prevalent in expert paddlers and raft guides. Correct equipment and techniques can aid the prevention of any type of injury. Considering this, injuries are relatively rare in both WW activities, especially those that are fatal. Research examining the occupational health of raft guides and other paddling tourist destinations than those mentioned in this review should be further developed and conducted.

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Table I Definition of the River Grades. (Based on the British Canoe Union Canoeing Handbook) [8]

Grade	Definition
I	Low difficulty river with slow moving water which is predictable. Obstacles are unobtrusive or non-existent. Hydraulics are small and cannot hold objects
II	Moderate difficulty river with slightly faster moving water than grade I rivers, therefore water movement is less predictable due to more obstacles. Hydraulics are medium sized, some may hold small objects. Routes are clear and visible.
III	Difficult river with fast flowing water which is less predictable than grade II. Obstacles may cause large hydraulics that will hold objects and push boats around or drops. Routes are recognisable
IV	Very difficult river with very fast flow and unpredictable water movement. Hydraulics are large and will hold objects with a strong force. Numerous hazards and obstacles above and below the surface. Inspection before running is recommended
V	Extremely difficult river. Similar to grade IV rivers but hazards, obstacles and hydraulics are more extreme. Inspection before running is required
VI	High-risk rivers that are generally classed as un-runnable. High risk of injury to participant if completed. Inspection essential before attempting but it is highly recommended to portage around these sections of river

Table II A summary of injuries and ill-health reported in white water adventure activities.

Population	N (Male)	Age (Years) (Mean \pm SD)	Type of Study/Data Source	Site(s)	Injury/Ill-health Type(s)	Possible Cause(s)	Severity	Intervention Suggestions	Comments	References
WW Paddling										
Competitive paddlers in the US	54 (75)	34 \pm 11.8	Survey (response rate 19.6%)	Shoulder most vulnerable. Head, neck, back, arms, elbows, wrists, legs, knees, hands and feet	Sprain, tendonitis, chronic, bruise, fracture, dislocation and laceration. Cold injury, frostbite, heat, dehydration, insect bite, near drown, drown	Carelessness; overuse injuries	Medical treatment was required for 19.6% of injuries reported	None	Generalizations between professional and amateur populations should be taken with caution. No clear definition of 'injury'. Injuries have been associated with specific sites on the body	10
WW rafters and paddlers	NI	NI	Observation and personal experience	Entire body at risk	Abrasions, lacerations, sprains, bone fractures and breaks, dislocation of joints, drowning	Inappropriate equipment or none at all. Poor risk assessment. Poor technique and levels of skills	Minor to fatalities	Use of correct equipment and techniques. Appropriate risk assessment. Seek expert advice before paddling a river	Based on personal experience. Conclusions were not based on any study-based evidence	11
Japanese canoe slalom team	417 (73.4)	26 \pm 2.9	Survey. Medical Examinations	Lower back, shoulder, elbow, knees	Numbness, limited movement, pain, fractures, dislocations, and osteoarthritis deformity	Stress from the paddle stroke is focused on the shoulder, elbow and lower back resulting in overuse injuries.	If untreated it can lead to fractures and deformation	Sufficient rest between training sessions. Strengthening the stability muscles	Objectively measured injuries through medical examinations	12
WW paddlers	392 (83)	34 NI	Survey distributed online, by post and face to face	Upper body, specifically shoulders	Abrasions; tendonitis; contusions; dislocations	Striking objects was the most reported cause of injuries. Stress from the force of the water causing injury followed	51% of the injuries required medical attention. 96% of injuries had either a good or complete	None	Novices developed more impact injuries from falling out of their boats. Expert paddlers developed chronic injuries mostly from overuse	16

Population	N (Male)	Age (Years) (Mean \pm SD)	Type of Study/Data Source	Site(s)	Injury/Ill-health Type(s)	Possible Cause(s)	Severity	Intervention Suggestions	Comments	References
WW paddlers	319 (72)	NI	Mail out mail back survey	Shoulder/arm; wrist/hand; head/face/neck; knee	Laceration, contusions and abrasions were most common acute injuries. Tendonitis, sprains/strains were most common chronic injuries	Accidents whilst transporting boats. Rodeo and slalom disciplines are at more risk of developing injuries	recovery Nonserious to requiring medical treatment	None	Subjective definition of 'injury', compared with medical assessment	18
Expert WW paddlers	25 (92)	34.1 \pm 9.4	Three- dimensional scapular and humeral kinematic data	Shoulder	Potential for acute and chronic injuries	Thrust motion of paddle stroke	Unspecified	Further research	Association found between shoulder stability and paddle stroke movement. Further research required to explore this association	25
WW rafting										
WWrafters and paddlers	NI	NI	Personal experience and observational data	Entire body at risk	Abrasions, lacerations, sprains, sprains, bone fractures and breaks, dislocation of joints, drowning	Inappropriate equipment or none at all. Poor risk assessment. Poor technique and level of skills	Minor to fatalities	Use of correct equipment and techniques. Appropriate risk assessment. Seek expert advice before paddling a river	Based on personal experience. Conclusions were not based on any study-based evidence	11
WW rafters Guides	390 (NI)	No mean. range 18– 60+	Mail-out, mail- back survey (response rate 15.5%)	Lower back, shoulder, elbow	Chronic back pain	Lifting, loading and uploading equipment	Short lived. Few needed medical treatment	Use mechanical lifts. Lift equipment in groups	Did not include individuals who may have retired due to injury. Low response rate. Only study assessing occupational health	17

Population	N (Male)	Age (Years) (Mean \pm SD)	Type of Study/Data Source	Site(s)	Injury/Ill-health Type(s)	Possible Cause(s)	Severity	Intervention Suggestions	Comments	References
Commercial WW raft users	30 providers ^a	NI	WW raft provider ^a records in the US	Face most common site. Upper and lower limbs	Lacerations, sprains/strains, fractures, contusions and dislocations in WW rafters.	Collisions with rocks, equipment and other rafters	Majority of injuries were minor	Fewer individuals per raft. Faceguards with the helmets	Faceguards can restrict vision, which can be an additional hazard	20
Commercial WW rafters	215 observations (53.5)	30.4 \pm 11.7	Hospital discharge data	Lower limbs most common site, specifically the feet. Face and shoulder	Fractures; non-fatal submersion; sprains/strains; contusions ; dislocations	Unspecified water transport accident. Submerged after falling out of the raft. Accident to watercraft causing injury. Unspecified fall in water transport	All injuries resulted in hospitalization	None	A standardized method of measuring injuries. Injuries that did not require medical attention have gone unreported. Explanations of the causes lack detail	22

Illness

WW Kayakers	92 (75)	29.3 \pm 8.72	Questionnaire and physical examination. Comparison to a control group of climbers	Ear	EACE	Exposure to sudden cold water. Frequency and years of experience were both positively correlated with EACE	69.5% of kayakers showed symptoms compared with 1.7% of the control group. 7.8% kayakers had severe case of EACE	The use of ear plugs reduced symptoms of EACE; however, these may create communication issues		13
WWrafters and paddlers	473 (NI)	NI	Survey. Water quality tests on water samples	Gastrointestinal	Gastrointestinal illness	River water ingestion. Consuming food and drink with contaminated hands	NI	Better hygiene after participation	Regular users experienced illness less frequently than those on daytrips. Possible explanations include: frequent users are more experienced and skilled therefore become	14

Population	N (Male)	Age (Years) (Mean \pm SD)	Type of Study/Data Source	Site(s)	Injury/Ill-health Type(s)	Possible Cause(s)	Severity	Intervention Suggestions	Comments	References
									submerged less frequently and ingest less water. Also, frequent users tended to live locally and therefore did not consume food directly after participation.	
WW canoeing competitors in Ireland	62 (89)	No mean. Median 22 (range 11–43)	Telephone questionnaire		Leptospirosis	Swallowing more than one mouthful of contaminated river water. Increased rainfall and release of hydroelectric water	18 individuals reported illness. Six confirmed cases of leptospirosis		A total of 62 of 69 competitors were interviewed over the telephone. A good sample from this specific event. However, because of such a specific event, findings are difficult to generalize	15

A Provider is a commercial organization which that sells adventure activities.

EACE external auditory canal exostoses, M males, NI no information, *WW = Wwhite Wwater

Table III A summary of injury rates reported in white water adventure activities

Population	N (Male)	Type of Study/Data Source	Injury Rates	Injury Severity	Reference
WW Paddling					
Competitive paddlers in the US	54 (75)	Survey	A total of 271 injuries were reported. An overall rate of 0.08 per participant per year	Medical treatment was required for 19.6% of all injuries reported	10
Japanese professional canoe slalom team	417 (73.4)	Survey and medical examinations	229 of 417 reported 288 problems. 22.5% experienced back pain. 21% experienced shoulder pain. An overall rate of 0.69 per participant	Numbness, limited movement, pain and dislocations. The medical examination identified fractures and osteoarthritis deformity from overuse	12
Recreational paddlers	319 (72)	Mail-out, mail-back survey	388 acute injuries reported (1.2 per person). 286 chronic injuries reported. A rate of 4.5 per 1,000 participant days	Medical attention was required for 47% of acute and 36% of chronic injuries. Shoulder and arm were the most acute injuries requiring medical attention. Back, chest and hip injuries had the longest duration	18
WW Rafting					
WW raft guides in America	390 (NI)	Mail-out, mail-back survey	77.4% experienced back pain	7.4% missed work. 20.8% experienced back pain >1 week Lifting and (un)loading of equipment were the best predictors of back pain	17
WW kayakers and rafters in New Zealand	142 providers ^a	Survey to access provider records of injuries	Kayakers 0.01 and rafters 0.54 per 1,000 participant hours	Injuries resulting in hospitalization for greater than 48hours were defined as severe	19
Commercial WW raft users in the US	30 providers ^a	WW raft providers in the US	0.26 per 1,000 participants	Sprains/strains (20%); lacerations (20%); contusions/bruises (18%); abrasions (11%); fractures (11%); dislocations (4%); Unspecified (8%); Unreported (9%)	20
Commercial WW rafters in New Zealand	215 hospitalizations identified (53.5)	Hospital discharge records over a 14-year period from the NZHIS	Overall rate of 1.04–1.81 per 100,000 participants	All injuries reported were injuries that resulted in hospitalization. Mean + SD hospitalization per annum 15.4 ± 6.0). Range 7–25	22

A Provider is a commercial organization that sells adventure activities.

M males, NZHIS New Zealand Health Information Service, WW = white water

Table IV A summary of fatality rates reported in white water adventure activities

Population	Type of study/data source	Fatality rates	Common causes	Comment	References
<i>WW paddling</i>					
Recreational WW paddlers	Data collected from managed river facilities	2.9 per 100,000 participants per annum	NS	This is an estimate as the actual number of participants was unknown. Does not account for paddlers who use unmanaged rivers	21
<i>WW rafting</i>					
Commercial WW rafters in New Zealand	Hospital records over a 14-year period from the NZHIS	33 fatalities reported in 14 years (81.8% M). 0.16-0.27 per 100,000 participants per annum	Drowning and submersion were the most common cause of death (94%). Accident to watercraft causing injury (3%) and unspecified fall in water transport (3%) were the other causes of death	Hospital records are an accurate measure of fatality rates, especially when compared against commercial usage	22
International tourist WW rafters and paddlers	Hospital records over a 14-year period from the NZHIS	6 WW rafting fatalities; 4 WW kayaking fatalities	NS	No information on participant numbers meant a fatality rate could not be calculated. Tourist data, therefore natives not included in these figures	23
WW rafters and paddlers	Tourist compensation claim data in New Zealand	0 WW kayak/canoeists; 2 WW rafters	NS	Only accounts for those individuals who claimed on their insurance	24

NS not specified, *NZHIS* New Zealand Health Information Service, *WW* white water