Chapter 7
Surfing Injuries

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Surfing: The Sport of Kings – History

Surfing is perhaps the oldest "extreme sport" in existence, and though its precise origins are unknown, most authorities agree that the sport originated in Polynesia

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over 800 years ago. The first written accounts of surfing appear in the journals of English explorer Captain James Cook, who witnessed Tahitians bodysurfing and riding waves in outrigger canoes in 1777 and a year later saw surfers riding waves while standing atop long wooden surfboards in Hawaii. Before the arrival of Westerners to Polynesia, surfing was an important cultural and recreational activity, particularly in the Hawaiian Islands where the chiefs maintained exclusive rights to the best surf breaks while commoners surfed elsewhere. By the early nineteenth century, the sport fell into a rapid decline under the influence of Western missionaries who discouraged surfing as a frivolous pastime [1].

Surfing's revival is widely credited to the charismatic Hawaiian waterman and Olympic swimming champion "Duke" Kahanamoku who introduced the sport to California and Australia in the 1910s. Commercialization of the surfing lifestyle through movies and music in the early 1960s led to rapid growth of the sport along both coasts of the United States and Australia and a gradual spread into Western Europe, Japan, Brazil, and Peru. During this era, the introduction of lighter foam-core fiberglass surfboards and neoprene wetsuits catapulted expansion of the sport beyond a small cadre of rugged individualists and into the mainstream [1].

The 1970s witnessed a revolution in surfboard design, with boards getting ever shorter, lighter, and more maneuverable. Shorter boards led to a new style of surfing which featured aggressive, carving, short-radius turns up and down the face of the wave, in contrast to the straight-line trimming and nose-riding of the past. These boards encouraged surfers to ride steeper, more tubular-shaped waves and allowed the surfer to generate speed along the length of fast-peeling waves. By the mid-1980s, surfers began experimenting with airborne maneuvers above the lip of the wave. A few years later, eleven-time world champion Kelly Slater began routinely landing aerials, giving him a competitive edge in surf contests.

Interest in big-wave surfing, which first developed along Hawaii's North Shore in the 1950s, was rekindled in the late 1980s as surfers ventured out to previously unridden surf breaks such as Maverick's (California), Dungeons (South Africa), and Killers (Todos Santos Island, Mexico) where waves over 10 m in height could be ridden given the right conditions. Catching these swiftly moving mountains of water required fast-paddling, long, tapered surfboards which tended to lack maneuverability and could become dangerously airborne during takeoff due to their large surface area. Though surfers were eager to push the size envelope, there were a few breaks such as Jaws (Maui) that on rare occasion produced even larger, faster-moving, gargantuan-sized surf. These waves appeared to be moving too fast to be caught by conventional means; no matter how daring, it seemed as if a paddling surfer could not generate the speed required to catch these behemoths.

Just when it seemed as if the upper limits of wave size had been reached, Laird Hamilton and others perfected the technique of using personal watercraft (PWC) to tow one another into yet larger waves in the 15+ meter range. Getting slung into waves from a PWC's towrope had a number of distinct advantages. It allowed surfers to ride less buoyant, faster, more maneuverable boards and to drop into the wave early and in optimum position. A system was devised whereby the driver

scoots into the white water at the end of the fallen surfer's ride to pull him out of harm's way using a rescue sled affixed to the stern of the PWC to aid in the retrieval process [1].

Though the conventional wisdom of "too big to paddle into" has been recently challenged, and some consider tow-in surfing a bastardization of the sport of kings, this variation of surfing caught on among many big-wave aficionados. Waves nearly 30 m in height have been successfully ridden by tow-in surfers at Cortez Bank, an underwater seamount 160 km off the shore of the California coast.

Stand-up paddle surfing (SUP), which involves standing on a wider, thicker surfboard using a long, single-bladed paddle for propulsion, began to catch on around 2005. SUP's appeal is that it is an excellent full-body workout that can be practiced on any body of water (river, lake, bay, ocean) and is relatively easy to learn. The paddling advantage afforded by a long paddle and the length and stability of the board make catching waves in the surf relatively easy, and the upright stance affords the rider an improved vantage point for spotting incoming swells. SUP has broadened surfing's playing fields and is currently the fastest-growing segment of the sport.

While surfing has always been primarily a recreational pursuit, early Hawaiian chants recount tales of surf contests held between chiefs where the victor would win floral wreaths, land, and other valuables. The 1960s surf boom led to a revival of surf contests with national contests being held in the USA and Australia in the early parts of that decade followed by international contests in the latter part of the decade. Professional contests sprouting up in the early 1970s and a world tour (currently the Association of Surfing Professionals [ASP]) followed shortly thereafter.

Most surfing contests are organized into 20- to 40-min heats of two to four surfers, scored by a panel of judges. The current ASP judging criteria look for the following elements when scoring a surfer's ride: "commitment and degree of difficulty; innovative and progressive maneuvers; combination of major maneuvers; variety of maneuvers; speed, power and flow." The sum of each surfer's top three rides is tallied, and the surfer(s) with the highest score advances into the next round until reaching the final. Currently, there are 65 ASP contests for men and 23 for women held in 6 continents. The top-tier ASP World Tour has 11 events taking place in Australia, South Africa, Brazil, Europe, mainland USA, Hawaii, and Tahiti with a total combined purse of US$9.3 million [2] (Fig. 7.1a, b).

Demographics

Estimates as to the number of surfers worldwide vary greatly. In 2002, Surfing Australia estimated that there were 17 million people who had surfed at least once in the last year, and in 2006 the International Surfing Association put that number at 23 million [3]. A survey by the Outdoor Foundation in 2009 estimated that 2.4 million people in the USA surfed at least once in the last year, with an average of 22

Fig. 7.1 (**a**) A floater is a maneuver where the surfer rides the breaking wave on top of it. Tel-Aviv beach. Surfer: Adi Gluska, (Photo: Roger Sharp). (**b**) A surfer uses a "cut-back" maneuver to get back to the lip of the wave, where most of its energy is concentrated. The Maldives Islands. Surfer: Adi Gluska, (Photo: Navi)

outings per year per surfer. They also found that 23 % were first-time participants, suggesting a continuing high growth rate [4].

Approximately 10 % of surfers are women, and it appears that the average age of surfers in the USA has been increasing over the last decade from the late 20s in 2000 to the mid-30s in 2009 [5, 6].

Surfing Equipment

Surfing, SUP, and Tow-In

Part of surfing's beauty lies in its simplicity. The only necessities are a board and a bathing suit, and the waves are free of charge. Though surfboards vary greatly in size and shape depending on the surfer's weight, ability, and riding style, the basic design and construction of most boards is similar; a foam "blank" is cut to shape and then sheathed in a fiberglass skin to create a lightweight but rigid structure. Polyurethane blanks are strengthened by a longitudinal, glued-in wooden stringer and covered with fiberglass which is saturated with polyester resin, while a more modern technique utilizes a polystyrene foam core and fiberglass saturated with a more durable epoxy resin. Anywhere from one to five fins (skegs) are placed at the tail end of the bottom of the board to give directional stability. The board's deck is coated with nonskid wax or foam pad to provide traction.

Most surfers utilize a leash (tether, leg rope) to prevent their board from being swept shoreward by the waves after a wipeout, thus averting a potentially long swim back to shore. Leashes are made of a thin flexible urethane cord affixed to the tail end of the surfboard's deck at one end and to the rider's ankle via a Velcro strap on the other.

The vast array of surfboard designs can be broken down into four broad categories: longboards, shortboards, SUP boards, and tow-in boards. The overall size (>2.5 M) of longboards makes them relatively stable and efficient to paddle. These characteristics make it easier to catch and ride waves, so these boards are well suited to beginners and favor a graceful, fluid riding style. Shortboards (<2.2 M) are much more maneuverable than longboards and are better suited for steeper, faster breaking waves. SUP boards are thicker, wider, and usually longer than longboards and provide a stable platform on which to stand. SUP boards designed for flat water paddling and racing are up to 5 m in length and relatively narrow, whereas those designed for riding waves tend to be shorter and wider. The single-bladed paddles used to propel an SUP board have a shaft that is approximately shoulder height and are made from rigid, lightweight materials such as carbon fiber. Lastly, tow-in boards, like water skis, are narrow, roughly 2 m in length, and equipped with foot straps so the rider can maintain control when going over chop at high speeds. These boards are heavily built to withstand the forces of the huge waves in which they are ridden and often weighted to prevent them from becoming airborne.

Bodyboarding and Bodysurfing

Bodyboards are used to ride waves in a prone position, with the rider wearing swim fins to aid in propulsion. These short (1.2 m), light, relatively inexpensive boards are made of closed-cell foam and lack fins, so collisions with one's board are relatively

harmless. Riding waves is easier than on a surfboard because the rider need not hop up into a standing position, so they are favored by beginners and young children. That being said, there is a cadre of hard-charging expert bodyboarders who ride some of the most technically challenging waves in the world.

Bodysurfing is perhaps the purest and likely the oldest form of surfing. When a meter or so in front of a breaking wave, the bodysurfer swims rapidly shoreward (aided by a short pair of swim fins) and utilizes their elongated body as a planing surface to ride the wave. Experienced bodysurfers extend an arm overhead to create a longer planing surface and increase speed and control.

Wetsuits

Modern neoprene wetsuits are remarkably lightweight, warm, and flexible. They vary in thickness and body coverage according to the water temperature in which they are intended to be used. Advances in wetsuit technology have allowed surfing to be a year-round sport and have expanded the sport's range to include Canada, Northern Europe, as well as the extreme southern latitudes.

In tropical climates, surfers often forgo a wetsuit in favor of a thin nylon "rash guard" which protects against chafe between board and rider and also functions as a sunblock. At the other end of the temperature spectrum, a full-body, hooded, 5–6-mm thick wetsuit, combined with neoprene booties and gloves, can keep a surfer warm for well over an hour in seawater approaching the freezing point. Wetsuits heated by means of a battery pack are now commercially available.

Injury Rates and Risk Factors

Despite its reputation as a dangerous activity, surfing has been found to be relatively safe as compared to more traditional sports. Lowdon's 1983 mail administered survey-based study of self-reported injuries among members of an Australian surfing club found 3.5 "moderate to severe" injuries (those that resulted in lost days of surfing or required medical care) per 1,000 surfing days [7]. More recently, Taylor's 2004 interviewer-administered survey found an injury rate of 2.2 significant injuries per 1,000 surfing days among a convenience sample of surfers at beaches in Victoria, Australia [8].

Lowdon's 1982 interviewer-administered survey of 79 professional surfers found the rate of moderate to severe injuries during practice or competition in that group to be 4 per 1,000 surfing days. He concluded that surfing was safer than professional rugby (55 injuries per 1,000 days), downhill skiing (6 injuries per 1,000 days), and American high school football (5.9 injuries per day) but riskier than men's gymnastics (1.8 injuries per 1,000 days) [9]. Over the period 1999–2005, Nathanson et al. prospectively studied acute injuries sustained at 32 professional and amateur surfing

contests worldwide. His group found that the rate of "significant injury" (those that resulted in lost days of competition or required acute medical care) was 6.6 per 1,000 hours of competition. This injury rate compares favorably to those found from studies of American collegiate football (33 per 1,000 hours), soccer (18 per 1,000 hours), and basketball (9 per 1,000 hours) in which similar methods of data collection and definition of injury were used [10].

A logistic regression analysis of Nathanson's data revealed that the relative risk of injury among contest surfers was greater when surfing in wave heights that were overhead or bigger relative to smaller waves (odds ratio 2.4), and that risk of injury was increased when surfing over a rock or reef bottom as compared to a sand bottom (odds ratio 2.6). In a study whose population were predominantly recreational surfers responding to a web-based survey, Nathanson found that the odds-ratios for significant injuries increased with age as well as with self-rated ability, and that there was no difference in injury rates between male and female surfers [10, 11].

Surfing Fatalities

The fatality rate for surfing is unknown. The Hawaii Department of Injury Prevention and Control reviewed the autopsy reports of 306 drowning deaths in the state of Hawaii from 1993 to 1997 and found that bodyboarders and surfers accounted for 17 of 238 ocean-related drownings [12]. During this 5-year period, there were also two fatal shark attacks on surfers. Though surfing is hugely popular in Hawaii year round, there are no reliable estimates of the number of surfers in the state.

An unpublished review of newspaper reports (by this author) searching the Nexus/Lexus database from 1984 to 1998 using the key words "surfer," "surfing," "death," "drowning," and "fatality" found accounts of 95 surfing-related fatalities in which cause of death was reported (though not confirmed). Drowning was stated to be the cause of death in 63 cases. Factors reported to be contributing to these drownings were concussions (11), seizures (4), and leash entanglement (4). Shark attacks were responsible for 12 deaths, lightning strikes for 8, and lacerations from surfboard fins for 2 others.

Acute Surfing Injuries

Acute Injuries and Their Anatomic Distribution

Outpatient studies of surfing-related injuries have found lacerations to be the most common, accounting for 35–46 % of all injuries, followed by sprains and strains, contusions, fractures, and joint dislocations (Table 7.1). Those same studies found the head and lower extremities to be the most commonly injured regions of the

Table 7.1 Acute and chronic surfing-related injuries from outpatient studies

Study	Nathanson [10]	Taylor [8]	Nathanson [11]	Lowdon [9]	Lowdon [7]
Population	Prospective study of surfers in competition	Convenience sample interviewed at beaches in Victoria, Australia	Web-based survey of English-speaking surfers	Survey of International Competitors	Members of Australian Surfing Assoc., Victoria, AU
Average age (SD)	24 (7)	28 (7.9)	29 (10.6)	22 (3.7)	22 (5.7)
Male gender	87 %	90 %	90 %	89 %	95 %
Average #'s of years surfing	Unknown	12	11	11 (5 days per week)	8 (2.7 days per week)
# of acute injuries	116	168	1,237	167	311
Type of acute injury					
Laceration/abrasion	35 %	46 %	42 %	45 %	44 %
Sprains/strains	39 %	29 %	12 %	37 %	29 %
Contusions	9 %	0	13 %	5 %	4 %
Fractures	5 %	9 %	8 %	10 %	16 %
Dislocations	4 %	11 %	2 %	2 %	1 %
Other[a]	9 %	5 %	23 %	1 %	6 %
# Chronic/overuse injuries	Unknown	71	477	20	26

[a]Includes tympanic membrane rupture, tooth fracture/avulsion, concussion, hypothermia, and near drowning

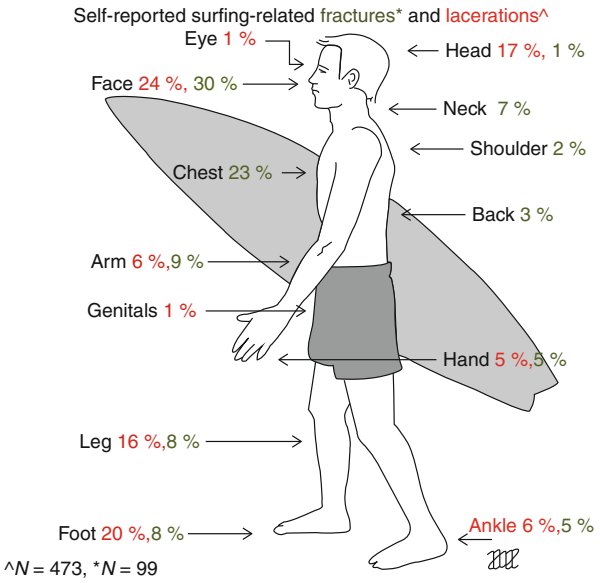

Fig. 7.2 Distribution of 572 self-reported surfing-related fractures and lacerations (Photo: Adapted from Nathanson et al. [11])

body. Figure 7.2 shows the anatomic distribution of lacerations and fractures from a study of 1,237 self-reported surfing injuries. Hospital-based studies of injured surfers, which in all likelihood consist of higher-acuity patients, show a higher percentage of head injuries and factures, than do outpatient studies (see Table 7.2).

Mechanisms of Injury

Understanding the common mechanisms resulting in surfing-related injuries is useful when caring for an injured surfer and is essential to the development of injury prevention strategies.

Surfboard

Nearly all studies exploring mechanism of injury have found that the majority of acute injuries are caused by collisions between surfer and surfboard (see Table 7.3). Most commonly, surfers are struck by their own boards, but they can also be struck by the boards of others, particularly in crowded surf breaks. Since the near-universal adoption of surfboard leashes, injuries from other surfers' loose boards have become less common, while injuries from the surfer's own board have become more common [7].

Riders collide with their own boards in a number of common scenarios:

- Rider is tumbled into own board by a wave's turbulence.
- During a steep takeoff, the board falls out from under its rider, and the rider inadvertently lands on his/her own board.

Table 7.2 Hospital-based studies of surfing-related injuries

Study	Allen [13]	Chang [14]	Taniguchi [15]	Taylor [8]	Hay [16]	Hay [16]
Population	Hospitalized patients, Kaiser Hospital, Waikiki (includes 12 bodysurfers)	Hospitalized patients, Queens Medical Center (includes 21 bodysurfers)	Emergency Department, Kahului Community Hospital	Emergency Department, Victorian public hospitals	Discharged home, Royal Cornwall Hospital (includes bodyboarders)	Hospitalized, Royal Cornwall Hospital (includes bodyboarders)
Location	Waikiki, Oahu	Oahu	North Shore, Oahu	Victoria, Australia	Cornwall, England	Cornwall, England
Number of subjects	36	47	90	267	190	22
Average age	20	Approximately 27	Unknown	75 % <30 years old	27	27
Male gender	92 %	Unknown	Unknown	83 %	80 %	80 %
Injury type						
Laceration	11 %	13 %[b]	83 %	47 %	38 %	0
Sprain/ligament rupture	5 %	13 %	0	12 %	21 %	0
Fracture[a]	30 %	45 %	7 %	14 %	14 %	64 %
Dislocation	5 %	2 %	3 %	2 %	13 %	10 %
Contusion	3 %	2 %	0	0	14 %	0
Drowning/near drowning	8 %	2 %	0	0	0	4 %
Solid organ injury intra-abdominal bleeding	17 %	2 %	0	0	0	4 %
Concussion/ intracranial	3 %	17 %	0	3 %	0	18 %
Tympanic membrane perf.	8 %	0 %	4 %	0	2 %	0
Other	8 %	4 %	0	21 %[b]	0	14 %[d]
Body region						
Head/face	39 %	34 %	49 %	42 %	42 %	18 %

Neck	17 %	21 %	0	3 %	7 %	18 %
Back	5 %	0 %	0	1 %	2 %	4 %
Thorax	0	4 %	12 %	6 %	4 %	0
Upper extremity	8 %	6 %		16 %	12 %	4 %
Lower extremity	6 %	19 %	31 %[c]	23 %	18 %	32 %
Intra-abdominal/ Retroperitoneal	14 %	2 %	0	0	0	14 %
Other/unknown	11 %	17 %	0	9 %	3 %	10 %

[a]Includes two tooth fractures
[b]Includes total of four eye injuries
[c]Includes upper and lower extremity injuries
[d]Includes laryngeal fracture and uretheral rupture

Table 7.3 Mechanism of surfing injuries

Study	Nathanson [10]	Taylor [8]	Nathanson [11]	Lowdon [9]	Lowdon [7]
Population	Prospective study of surfers in competition	Convenience sample interviewed at beaches in Victoria, Australia	Web-based survey of English-speaking surfers	Survey of International Competitors	Members of the Australian Surfing Assoc., Victoria, AU
Average age (SD)	24 (7)	28 (7.9)	29 (10.6)	22 (3.7)	22 (5.7)
Male gender	87 %	90 %	90 %	89 %	95 %
Average #'s of years surfing	Unknown	12	11	11 (5 days per week)	8 (2.7 days per week)
# of acute injuries	116	168	1,237	167	311
Cause of acute surfing injury					
Surfboard	29 %	42 %	66 %	47 %	53 %
Seafloor	24 %	18 %	17 %	9 %	13 %
Wave force/"wiping out"	12 %	36 %	7 %	≥4 %	≥6 %
Body motion	16 %	0	5 %	16 %	17 %
Marine animal	2 %	1 %	3 %	0	1 %

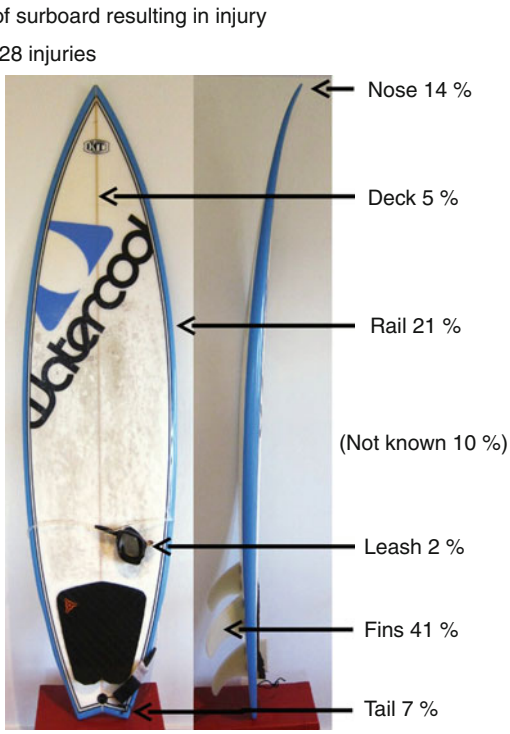

Fig. 7.3 Board-related surfing injuries (Photo: Nathanson, Haynes, Galanis [11])

- After a wipeout (particularly in offshore winds), the surfboard becomes airborne and comes down on the riders head as he/she surfaces.
- After a wipeout, the board is pulled shoreward by a wave until its leash is pulled taught. The board then recoils back on its leash along the surface, striking rider (often in the face).
- While attempting to "duck dive" under an oncoming wave, the board is forcefully thrust back by the wave's force into the surfer.

Many serious board-related injuries occur when a surfer falls onto or is forcefully struck by sharp parts of the board such as the fin(s) (skeg), nose, or tail (Fig. 7.3). Lacerations obtained from the surfer's own surfboard fins account for as many as 30 % of all significant surfing injuries in some studies and usually involve the lower extremities or head [7, 11] (Fig. 7.4a). Surfboard fins are rigid, have sharp trailing edges and tips, and are capable of inflicting deep lacerations which may involve tendons, arteries, and nerves. Though the majority of fin-induced lacerations are superficial, their potential to cause penetrating trauma should not be underestimated; fatal and near-fatal fin-induced lacerations of the aorta and femoral arteries have been described, as have eviscerations and rectal injuries [17].

Kim et al. reported a series of 11 severe surfboard-related ocular injuries, 5 of which resulted in globe ruptures and permanent monocular loss of vision. Zoumalan described a series of 3 similar injuries. Recoil of the board on its leash causing the

Fig. 7.4 (**a**) Fin induced chin laceration (Photo: SurfCo Hawaii) (**b**). Fin induced thigh laceration (Photo: SurfCo Hawaii)

pointed nose of the board to strike the surfer's eye was cited in both studies as being a common mechanism of ocular injury. Fractures of the orbital wall have also been reported [18, 19].

Blunt trauma from collisions with rounded parts of the surfboard such as the rails and deck is also frequent and usually results in contusions. However, forceful blows to poorly padded parts of the body such as the scalp, face, and shins can cause lacerations and fractures. Nasal bone fractures, tooth avulsions, and other maxillofacial fractures from impact with a surfboard are relatively common. Loss of consciousness secondary to blunt head trauma from a surfboard has led to drowning deaths among beginner as well as elite surfers.

Blunt trauma to the abdomen and chest has been reported to cause splenic rupture and pneumothorax, respectively [8, 13]. Even foam bodyboards have been reported to cause liver and splenic lacerations during wipeouts in which the nose of the board sticks into the sand and the tail is thrust under the rider's ribs [20].

Seafloor

While water is a forgiving surface on which to fall, the same cannot be said of the seafloor. Indeed, some of the most severe surfing-related injuries occur when those riding waves in shallow water fall and hit bottom headfirst.

Because small waves break in shallow water (waves begin to break at a depth of approximately 1.3× the wave's height), striking the seafloor is most common in small surf [21]. However, the large, powerful, tubular waves sought out by expert surfers for "tube riding" also put the rider at significant risk for striking the seafloor. These tube-shaped waves only form in places with a steeply inclined seafloor (e.g., a reef or a ledge), and while these waves begin to wall up in deep water, their lip may come crashing down in the shallows (Fig. 7.5). A surfer falling in the wrong part of such a wave runs the risk of getting carried "over the falls" by the wave's lip and driven onto shallow reef. At Oahu's famed Pipeline, the inner portion of the reef is a mere 1–1.5 m deep, and the fearsome tubular wave at Teahupoo, Tahiti, breaks over an even shallower reef. Experienced surfers have sustained fatal head injuries at both venues.

Abrasions and superficial lacerations obtained from getting dragged by wave action over coral reef are so common among surfers as to have been dubbed "reef rash." These wounds are often embedded with fine particles of coral and are highly prone to infection. Foot lacerations and plantar puncture wounds acquired by stepping on sharp objects are also commonplace, particularly in tropical waters where the seabed is often littered with spiny marine animals, shell fragments, and coral reef. These too are also highly prone to infection and usually occur when entering or exiting the water or while retrieving one's surfboard.

Catastrophic spinal cord injuries due to surfing, bodyboarding, and bodysurfing are well documented and are similar to those seen in shallow water diving accidents. The usual scenario is one in which the surfer wipes out striking bottom headfirst and causing excessive axial loading, hyperextension, hyperflexion, or rotational injury

Fig. 7.5 Surfer coming out of a barrel (tube ride). Surfer: Adi Gluska, (Photo: Jhon Callahan)

to the cervical spine [22]. Though some surfers take a casual approach when surfing over a sandy bottom, packed wet sand can be very unforgiving, and headfirst falls onto sand bottoms have resulted in a number of well-publicized and tragic cases of quadriplegia among young surfers [23].

Because bodyboarders and bodysurfers ride headfirst in a prone position, often in near-shore plunging waves, they are at particularly high risk for injuries to the cervical spine. Cheng described a series of 14 cervical spine injuries among bodyboarders and concluded that many of these injuries appeared to be associated with spinal stenosis and cervical spine osteophytes [24]. Chang et al. analyzed 77 patients who suffered wave-related spinal cord injuries in Hawaii. The typical victim was a male tourist of large build in his 40s, with little previous experience in wave-riding activities [25].

Any surfer seen floating on the surface or complaining of severe neck pain after a wipeout should be presumed to have suffered from an unstable cervical spine fracture until proven otherwise. A surfboard and rolled towels on each side of the head can be used to make an improvised backboard and provide spinal immobilization to transport such patients (Fig. 7.6).

Other potential hazards involving the seabed are underwater rock or coral overhangs and obstructions such as kelp or crab traps, which can snag a surfer's leash, tethering them underwater. There are a number of instances in which surfers have had their leashes snagged underwater, were unable to rapidly disengage from the leash's ankle strap, and subsequently drown. Other leash-related injuries occur when an extremity is caught in a loop of leash during a wipeout and the leash is subsequently tugged taught by the force of a wave on the surfboard. Most common

Fig. 7.6 Improvised cervical immobilization. A board, towels, surfboard leash, and roof straps can be used to maintain spinal immobilization in a surfer with a presumed cervical spine injury (Photo: Yaron Weinstein)

among these are fractures and dislocations of the interphalangeal joints, but finger amputations via this mechanism have also occurred.

Wave-Force Injuries

The energy of a breaking wave is considerable. It has been estimated that a 1-m-wide slice of a 3-m-high wave has the equivalent of 73 hp, and because a wave's power increases as a square of its height, a 6-m wave is four times as powerful [21]. Most of a wave's kinetic energy is dissipated in its cascading lip, but not all waves are created equal. Chang et al. describe a four-level grading system that categorizes beaches by the power of the surf, with gentle spilling waves (grade 1) produced in areas with gently sloping bottoms being the least dangerous type and hollow plunging waves (grade 4) found in areas with a steeply inclined bottom being the most dangerous. In his Hawaii-based study of wave-related accidents resulting in cervical spine injuries, 96 % occurred at grade 3 or grade 4 beaches [25].

Surprisingly, traumatic injuries caused solely by the hydraulic forces of a wave (i.e., not involving surfboard or seafloor) are rare, even in very large surf. Most susceptible to wave-force injury is the tympanic membrane (TM). TM rupture can occur when a surfer is hit by the lip of a large wave or when the ear slaps into the water after a high-speed wipeout. Most ruptures involve the pars tensa, below the umbo and malleolus, and heal spontaneously in 4–6 weeks. Immediate symptoms involve conductive hearing loss, ear pain, and the ability to blow air outward through the ear with a pinched nose. There may also be a bloody discharge from the ear [26]. In order to prevent infections of the middle ear, surfers should be advised to keep the ear dry (no surfing, ear covered in the shower) for 4–6 weeks. Rare instances of nonhealing should be referred to an ENT for tympanoplasty. Dizziness or vertigo implies a concomitant rupture of the oval or round windows; these too usually heal spontaneously.

Long bone fractures, shoulder dislocations, and other significant injuries have been attributed to getting hit by enormous waves, but such injuries are unusual unless a surfer hits bottom or is struck by a surfboard.

A much greater danger in large surf is the risk of being held forcefully underwater by a breaking wave's turbulence. Though underwater hold-downs almost never exceed 30 s, even in huge waves, that may be long enough to test the limits of an already winded surfer [27]. Many tow-in surfers wear flotation vests to improve buoyancy in the highly aerated water that is formed after large waves break and a wetsuit is currently being developed with an air bladder that can be rapidly inflated by means of a CO_2 cartridge [28].

Every big-wave surfer's greatest dread is a two-wave hold-down in which they are unable to surface from one wave before getting washed over by the next. While many of today's most notable big-wave surfers have described near-death experiences from getting held under by multiple waves, the fact is that in the absence of trauma, drowning among experienced surfers is exceedingly rare. The number of big-wave surfers that have drowned over the last three decades is in the single digits, and to this author's knowledge, no one has ever drowned while tow-in surfing, despite the fact that tow-in teams have been chasing the largest rideable swells on the planet for over 15 years.

Strong seaward-flowing currents known as "rip currents" (and improperly known as riptides or undertow) pose another danger to those in the surf zone, primarily to inexperienced surfers who fail to appreciate the complex patterns of water flow generated by breaking waves. Experienced surfers use these currents to advantage when paddling out to a surf break, but surfers attempting to reach shore after having lost their boards may find themselves struggling to swim against an outflowing rip current and can become exhausted and drown. According to the United States Lifesaving Association, over 80 % of lifeguard-assisted rescues on ocean beaches are due to rip currents. Surfers who are poor swimmers, lack aerobic capacity, or are inebriated are at particularly high risk of drowning.

Wave-Riding Injuries

Over the last two decades, surfing has become an ever more acrobatic and dynamic sport, particularly at the elite levels. As such, acute muscle and joint injuries acquired while riding waves are on the rise among today's top surfers. In a 2007 study of injuries occurring during surfing contests, 19 % of all acute injuries were found to be knee sprains and strains, up from 10 % reported in a 1987 study [9, 10].

Aerial maneuvers in which the surfer steers sharply up a wave face, becomes airborne, and then lands back on his board carry a high degree of difficulty and score highly in competition (Fig. 7.7). Successfully landing these maneuvers requires that the surfer land on the moving face of the wave with the board squarely under his feet. Mid-flight control of the board is usually achieved by grabbing a rail of the board from a crouched position, but, when landing, the surfer relies solely on air pressure to maintain foot contact with the board, then must compress to absorb the shock of landing. Aerials in which a surfer lands on his board awkwardly or comes down abruptly have become an increasingly common source of ankle and knee injuries. It is now common to see professional surfers sidelined by ankle

Fig. 7.7 Adi Gluska, airborn. The Maldives Islands (Photo: Shiran Valk)

sprains and fractures as well as ACL rupture and injuries to the meniscus from ill-fated aerials. When wave riding, the knee of the back leg (usually the dominant leg) is in a flexed valgus position, placing high loads on the medial collateral ligament during forceful maneuvers [26].

Radical snaps and laybacks (short-radius turns) requiring highly contorted body positioning are also mandatory for competitive success (Fig. 7.8). These moves demand that the surfer generate power from the relatively unstable surface of their surfboard while riding over the moving and uneven surface of a wave. Poor technique, lack of flexibility, and failure to properly warm up can contribute strains of the hamstrings, neck, and back while executing these aggressive turns.

Overuse Injuries

Given that surfing can only be practiced when there are adequate waves, surfing is an intermittent activity in most areas, even among the sport's most avid participants. High-quality surf is generated by long-period ocean swells originating from distant storms, and these swells typically last anywhere from 2–6 days. When surfing conditions are optimal, surfers may spend upward of 4 h in the water (Mendez), but lack of surf in a given locale may preclude surfing for weeks on end.

Time-motion analysis studies have found that 50 % of a surfer's time is spent paddling and 45 % is spent remaining still, while only 3–5 % is spent actually riding

Fig. 7.8 An off-the-lip is one of the core maneuver of modern surfing. The Maldives Islands. Surfer: Adi Gluska, (Photo: Shiran Valk)

waves, so it comes as little surprise that most overuse injuries stem from paddling [29, 30]. Sustained paddling is required to get out to the takeoff zone and maintain one's position in the presence of currents, while short bursts of paddling at maximum effort are needed to successfully catch waves, dodge unfavorable waves, and avoid oncoming surfers.

Lowdon et al. found that among a group of world-class competitive surfers, 29 % of all sprains and strains were related to paddling. In Nathanson et al.'s Internet-based survey, which included 477 surfing-related chronic health problems, overuse injuries to the shoulder (18 %), back (16 %), neck (9 %), and knee (9 %) were most frequently cited [9, 11]. Taylor et al. reported 146 chronic health problems among surfers. He found that pain or stiffness of the neck and back, shoulder, and knee comprised 20% 10% and 8 % of these problems, respectively [8].

Surfers are notorious for not warming up prior to surfing [7, 9]. A fitness program emphasizing flexibility, core strength and balance, as well as a warming up before surfing should be advised as a means of decreasing the incidence overuse injuries.

Neck and Back Pain

Correct prone paddling posture requires extension of the lumbar and thoracic spine so as to raise the upper chest off the deck of the board and allow for an ergonomic paddling stroke. The neck is held in slight extension (Fig. 7.9).

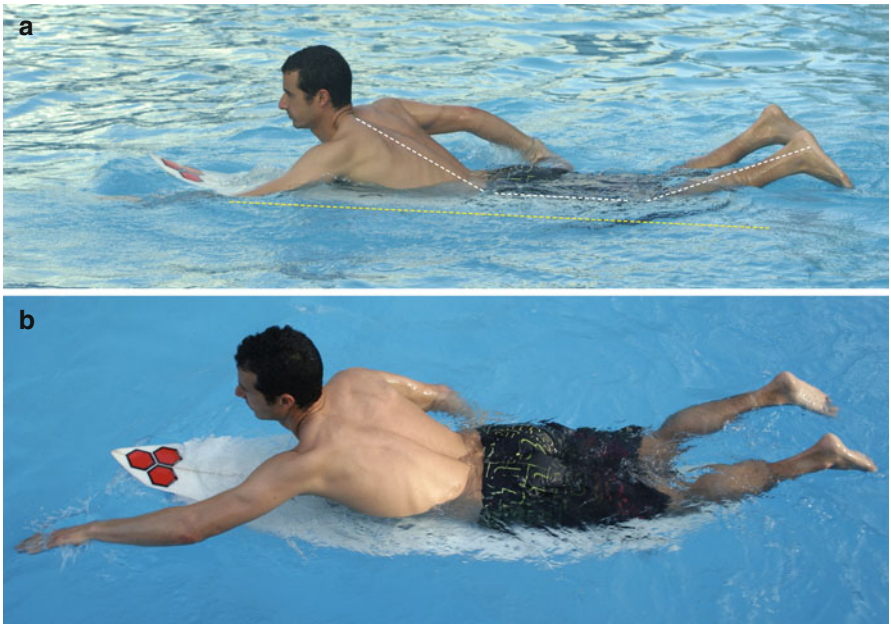

Fig. 7.9 (**a, b**) Surfer paddling. Note chest is raised off board resulting in excessive lordosis (hyperextension of lower back) which by placing the posterior spinal column under continued stress may lead to a stress fracture (spondylolysis) (Photo: Yaron Weinstein)

Strains of the lumbar and cervical paraspinous muscles are common, likely due to sustained isometric contraction of those muscles while paddling. Beginners and those surfing after prolonged periods of inactivity often complain of burning muscular pain in the upper trapezius and rhomboid muscles due to overuse. Neck soreness can be exacerbated by the tendency of some surfers to hyperextend the neck to compensate for inadequate back extension due to fatigue or lack of lumbar and thoracic flexibility [31].

Most neck and back spasms caused by overuse resolve spontaneously, but massage, physical therapy, and chiropractic manipulation can improve acute symptoms. A proper warming up prior to surfing (particularly in cold waters) and routine stretching of the low back, hamstrings, and hip flexors may help prevent this common problem [26]. Actively engaging the core musculature while paddling creates a firm paddling platform, unloading the muscles of the low back. For this reason, land-based exercises aimed at improving core strength among surfers are important. Gillam et al. demonstrated that while surfers had more powerful shoulder flexion and extension than other athletes, they had significantly weaker abdominal strength [6].

Neck pain not resolving after conservative treatment may be due to cervical disk injury, degenerative arthritis in older surfers, or the thoracic outlet syndrome.

Focal low-back pain in adolescent surfers should raise suspicion for spondylolysis, which can be found among other athletes in sports which require low-back extension such as gymnastics and American football. Symptoms are exacerbated by

movements that forcefully extend the low back such as duck diving under oncoming waves or popping up (moving from a supine to a standing position) on a surfboard. A one-legged standing extension test reproduces the pain caused by spondylolysis, and a bone scan alongside CT scan and MRI can be obtained to confirm the diagnosis. Stress fractures of the pars interarticularis generally heal with conservative therapy but often require 4–6 months of cessation from sports, though some may require spinal fusion later in life [32].

In 2004, Thompson first described a case series of nine nontraumatic spinal cord injuries among neophyte surfers that he termed "surfer's myelopathy." Afflicted surfers describe feeling low-back pain within an hour of surfing and within the next few hours develop lower extremity weakness, urinary retention, and paralysis [33]. In many cases recovery is complete, but in some instances the victim is left with permanent neurologic deficits including quadriplegia. MRIs of these patients demonstrate findings consistent with thoracic spinal cord ischemia which has been postulated to be caused by kinking or vasospasm of the spinal arteries brought about by the prone hyperextended posture assumed when paddling (Fig. 7.9). Most case series describe this syndrome in first-time surfers who are healthy young adults with normal anatomy and normal coagulation profiles [34, 35]. It remains a mystery why this syndrome only occurs in first-time surfers.

Upper Extremity Pain

Surfing, like swimming, is an overhead sport, and by one estimate, a surfer may take as many as 2,000 paddling stokes in a 2-h session. Shoulder strains and impingement syndromes of the supraspinatus tendon caused by paddling are very common, and intermittent shoulder pain has been found to affect nearly 30 % of amateur surfers [36].

Surfers with scapular instability, muscle imbalance, or poor paddling biomechanics are particularly predisposed to shoulder problems. Those who fail to raise their chests off the deck of their board while paddling require more shoulder flexion during the recovery phase of the paddling stroke, overloading the relatively hypovascular zone of the supraspinatus tendon [31].

Muscle-bound surfers who rely on surfing as their primary means of exercise are prone to shoulder imbalance due to overdevelopment and shortening of the pectoralis and anterior deltoid muscles and relative weakness of the rhomboid muscles, subscapularis, and other scapular stabilizers [36]. This muscular imbalance leads to scapular protraction and movement of the humeral head high into the shoulder socket resulting in compression of the rotator cuff tendons and subacromial bursa, which in turn can cause tendinitis and bursitis [37]. Years of surfing can lead to fraying of the supraspinatus tendon as it courses under the acromion which can progress to a torn rotator cuff.

Shoulder rehabilitation begins with a period of rest, anti-inflammatory medication, and ice. A few days of rest should be followed by gentle stretching of the

shoulder using pain as a limiting factor. Early mobilization should include a progressive program of exercises to strengthen the rotator cuff muscles and scapular stabilizers. Each session should begin with isometric muscle contraction and progress to isokinetic exercises. At first, use only the weight of the arm and then advance to light weights or elastic bands, using pain as a rate-limiting factor. A return to surfing should only occur upon restoration of a painless full range of motion, at first surfing on a relatively buoyant, easy gliding board to reduce the paddling burden. Shoulder rehabilitation should last a minimum of 6–12 weeks and may take up to a year.

The repetitive stresses of paddling, duck diving, and popping up may cause lateral epicondylitis or triceps tendinitis. Treatment initially involves cessation of surfing, anti-inflammatory medications, and icing, followed by physical therapy [38]. After a period of conservative treatment, the athlete should return to surfing on a board with efficient paddling characteristics as above. Cho-Pat strapping and various injectables (steroids, PRP, autologous blood) may help alleviate chronic lateral epicondylitis.

Environmental Injuries

The surf zone can be a hostile environment with unremitting exposure to solar radiation, prolonged immersion in salt water, and potential threat from hazardous marine life.

Skin, Eyes, and Ears

Incident and reflected sunlight can take a toll on a surfer's skin and eyes. A small study conducted at a surfing contest in Texas (USA) found that surfers have a higher rate of basal cell carcinoma than their age-matched non-surfing counterparts [39]. It is likely that due to their (often unprotected) prolonged exposure to harmful ultraviolet radiation, surfers are also at increased risk for squamous cell carcinoma and malignant melanoma.

Physical barriers such as wetsuits, rash guards, and hats are the most effective and reliable way for surfers to protect themselves from the sun. In warm climates, long-sleeved, hooded rash guards with SPF >50 should be worn. In smaller surf, hats with chinstraps and sunglasses or goggles with retention straps can be worn. Broad-spectrum (UVA and UVB), water-resistant sunscreen with SPF >15 should be applied to the face and other uncovered skin 30 min prior to entering the water, using approximately 30 ml for an unclothed adult male. Despite manufacturer claims, most sunscreens do not last for more than 2–3 h in the surf and need to be reapplied. While there is good evidence that sunscreen provides protection against squamous cell carcinoma, there is only fair evidence that it protects against basal

cell carcinoma and virtually no evidence that it protects against malignant melanoma [40]. Heavily sun-exposed, fair-skinned, and older surfers should be examined at least annually by a dermatologist to screen for skin cancer.

Repeated exposure to bright sunlight, wind, dust, and salt spray can lead to triangular yellow growths over the nasal aspect of the conjunctiva, known as pterygia. Often seen among those surfing in sunny climes, these benign fibrovascular growths can cause eye irritation and may affect vision if they extend over the cornea. Use of sunglasses or goggles on and off the water can prevent the formation and growth of pterygia. Pterygia affecting vision should be referred to a corneal specialist and may be amenable to surgical removal.

External auditory canal exostosis (EAE) or "surfer's ear" is remarkably common among surfers. These painless bony growths of the external auditory canal are benign but can cause water and other debris to get trapped in the ear canal leading to recurrent bouts of otitis externa. Severe exostosis, blocking greater than 66 % of the ear canal, may also cause some degree of hearing loss.

Wong et al. examined the ears of 307 surfers at the US Open of Surfing and found that the overall prevalence of EAE was 73.5 %. In the group that had surfed for over 20 years, 91 % had evidence of EAE, with 16 % of that group having severe exostosis [41]. Kroon et al. showed that those who surfed predominantly in colder waters were at significantly increased risk of EAE (odds ratio 5.8), and that the number of years surfed increased one's risk of developing exostosis by 12 % per year [42].

Broad-spectrum antibiotic drops containing a steroid and an analgesic (e.g., Cortisporin otic suspension) should be prescribed to surfers with otitis externa. Among surfers who frequently suffer from otitis externa (both with and without exostosis), drying the ear canals with isopropyl alcohol after surfing is recommended. The use of Q-tips or other objects in the ear canal should be highly discouraged as this often leads to otitis externa.

Though never proven, the consensus among otolaryngologists is that earplugs can prevent the formation of bony exostosis. Large exostoses causing a decrease in hearing or leading to recurrent episodes of otitis externa should be removed using a transcanal approach by an otolaryngologist experienced in this procedure. After the procedure, surfers are usually "dry-docked" for 4–6 weeks. Unfortunately EAE often regrow after surgery.

Hazardous Marine Life

Despite the widely held perception that dangerous marine animals, most notably sharks, pose a significant risk to surfers, less than 3 % of all surfing injuries are caused by marine life, and the majority of them are due to jellyfish and sea urchins (Table 7.3). Annually there are approximately 30 shark attacks on surfers worldwide with a fatality rate of less than 8 %. The prevention and treatment of marine bites and stings are beyond the scope of this chapter, but a summary of recommendations can be found in Table 7.4.

Table 7.4 Treatment of bites and stings from hazardous marine animals

Animal	Habitat/range	Injury/symptoms	Treatment	Prevention
Sea urchin	Rock/reef bottom	Puncture wounds with retained spines Venomous species	Surgically remove spines in fingers or joints. Other spines best left in place Envenomation: soak in hot water (45°C) for 15–30 min	Booties. Avoid stepping on seafloor
Stingray	Sandy bottom	Jagged wound and envenomation. Radiating pain nausea and vomiting	Soak in hot water (45°C) for 15–30 min Remove retained spine and sheath Prophylactic abx's Leave wound open versus loose closure	Shuffle feet to scare away animals
Shark	Near steep drop-offs, seal breeding colonies, river mouths	Deep lacerations, hemorrhage, avulsion	Apply direct pressure or tourniquet In OR, repair damaged structures loose closure Prophylactic abx's	Avoid surfing at dawn, at dusk, in murky water, or alone. If shark of >2 m is seen, slowly exit water
Jellyfish	Warm waters worldwide	Painful sting, whiplike rash on exposed skin Allergic reactions	Flush skin with seawater Topical steroid crème for dermatitis Portuguese man-of-war: hot water Australian box: vinegar, antivenom Hawaiian box: hot water Allergic rxn: standard treatment	Rash guard or wetsuit Safe Sea® lotion on exposed skin
Sea bather's eruption	Warm waters, summer (jellyfish larvae)	Extremely pruritic papular rash on *clothed* skin surfaces	Topical steroid crème Oral diphenhydramine	Remove wetsuit or bathing suit before exiting water
Stonefish	Indo-Pacific, rock or reef bottom	Painful sting, severe edema of foot	Soak in hot water (45°C) for 15–30 min Remove retained spine if presented Elevate extremity	Avoid stepping on seafloor

Wound Care

Lacerations, abrasions, and puncture wounds are a major reason for surfers to seek medical care. Several factors should be considered when treating these injuries.

The sea is home to a variety of human pathogens such as *Vibrio, Mycobacterium, Pseudomonas*, and other gram-negative organisms, many of which are not sensitive to antibiotics commonly used to treat soft tissue skin infections. When treating a wound infection acquired in the marine environment or providing prophylactic antibiotics, consider adding an antibiotic such as doxycycline or ciprofloxacin to cover marine flora. Most marine organisms are halophilic (salt loving) and will not grow in standard culture media, so when obtaining a wound culture, alert the laboratory to the need for specialized culture media [43]. *V. vulnificus* and *V. damsela* have been reported to cause severe wound infections among surfers. Because of their propensity to cause necrotizing fasciitis, severe infections from these organisms are best treated with intravenous imipenem [44].

Like other extreme athletes, surfers tend to be a hardy breed, and if wave conditions are good, they will return to the water after wound repair, despite advice to the contrary. Nonabsorbable sutures and staples hold up best in the marine environment, whereas surgical adhesives and wound closure strips tend to slough off. For those insistent on surfing, a waterproof wound dressing that will hold up to the rigors of the surf zone can be made as follows: After a wound has been closed, apply a thin layer of an antibiotic ointment to the wound, cover it with a flexible adhesive bio-occlusive dressing, and cover that with a sturdy reinforced tape such as duct tape. If feasible, a wetsuit or wetsuit bootie should be worn over the injured area for further protection. Upon return to shore, the dressing should be removed, the wound rinsed with clean fresh water, and another layer of antibiotic should be applied to the wound which is then covered by a standard gauze dressing.

Coral abrasions require scrubbing and copious irrigation to remove any retained coral fragments and minimize the risk of infection. After these wounds have been thoroughly cleansed, they should be coated with antibiotic ointment and then covered with a nonadherent dressing.

Plantar puncture wounds acquired in the marine environment warrant a high index of suspicion to rule out the presence of retained organic material including sea urchin spines, coral reef, and shell fragments. Most of these foreign bodies contain calcium and are well visualized with x-ray or ultrasound. Due to the high incidence of infection associated with puncture wounds to the foot, prophylactic antibiotics which include coverage for marine organisms are indicated.

Painful ulcers, termed “sea ulcers,” commonly form on the hands, feet, and legs of surfers who have prolonged daily exposure to salt water. These ulcers typically begin as small nicks and abrasions caused by coral reef or rocks but fail to heal and gradually enlarge because repeated soaking in the ocean prevents a protective scab from forming. Without a scab, the delicate collagen matrix essential for the initial stage of the healing process gets washed away each surf session, eroding underlying tissue. Constant friction between a surfer’s skin and board, especially at the tops of the feet and knees, can further compound the problem.

While often moist at the base, sea ulcers are typically sterile and generally heal within a few weeks of cessation of surfing. To promote healing, ulcers should be covered with dry gauze to prevent soiling but at bedtime should be left uncovered so they can dry. Particulate matter such as sand, which often gets trapped in sea ulcers of the lower extremity, should be removed. For those who continue to surf, a waterproof dressing as described above can be used when surfing [26].

Injury Prevention

Basic Safety Recommendations

- All surfers should be strong swimmers who can swim 1 km in less than 20 min and are comfortable swimming alone in the ocean [45].
- Each surf break is unique and has different characteristics depending on wave height, tide, and wind. When surfing in a new locale, surfers should familiarize themselves with safe entry and exit points, currents, and underwater hazards. This is best done by talking to local surfers and observing the surf break for a minimum of 10 min prior to entering the water.
- Surfing is a skill sport that takes many, many years to master. Surfers should respect their own limits and gradually work their way up the ladder in terms of wave size and difficulty.
- Surfing to exhaustion, particularly in large surf, is foolhardy. Wise surfers pace themselves so that at any given moment they are able to hold their breath for at least 20 s in preparation for an unexpected hold-down. Fatigued surfers should paddle to shore or rest outside of the takeoff zone.
- Breath-hold training may induce syncope and should only be practiced on land in a safe, supervised environment.

Equipment

Collisions with surfboards are the leading source of surfing injuries with 60–70 % of those injuries inflicted by the board's sharp fins, nose, or tail (Fig. 7.2). Minor modifications in surfboard design, described below, are unlikely to significantly alter performance characteristics and would likely go a long way toward reducing injury rates.

- The Surfrider Foundation Australia suggests that sharp surfboard noses and tails should be rounded off to a minimum radius of 37 mm. At the very least, the sharp nose of a surfboard should be covered with a shock-absorbing rubber tip.
- Trailing edges of surfboard fins should be dulled to a minimum width of 2 mm with fine-grit sandpaper. Rubber-edged fins are commercially available and are highly recommended. Fins should be designed to break away on impact.

- Beginners should use boards made entirely of shock-absorbing closed-cell foam and equipped with flexible rubber fins. These boards provide an extra measure of safety for neophytes who have minimal board control or familiarity with the surf and are at high risk of being struck by their own boards. These boards also reduce the risk of injuring near by surfers
- In all but small, uncrowded surf, a leash should be used. Leashes keep the surfer's board close at hand, and the board can be used as a flotation device should a surfer become exhausted or injured. Leashes also reduce the risk of a loose board injuring another surfer [46]. All leashes should be equipped with a single-pull quick-release mechanism should the surfer need to rapidly disengage from the leash (e.g., leash snagged on seafloor). In large surf, a stronger, longer leash is less likely to break and will keep a surfer farther away from his or her board.

Personal Protective Gear

- Temperature-appropriate wetsuits should be worn because they protect against hypothermia, provide a modicum of flotation, provide abrasion resistance, and block harmful UVA and UVB solar radiation. In warmer waters, a long-sleeved rash guard should be worn to provide protection from the sun as well as from jellyfish stings.
- Studies have shown that 26–49 % of surfing injuries involve the head and occasionally result in loss of consciousness and drowning, so it makes sense for surfers to wear helmets. Although surfing-specific helmets are commercially available, studies have shown that few use them. Many surfers perceive helmets as restrictive, feel they restrict hearing and sense of balance, and are concerned that the additional surface area will interfere with duck diving [11, 46]. Surfers should use a helmet when surfing in large hollow waves over a shallow reef, in crowded conditions, or if they are learning how to surf using a traditional fiberglass/epoxy surfboard.
- Booties should be considered to prevent foot injuries when surfing over coral reef.
- Earplugs and/or a neoprene cap should be considered to prevent surfer's ear.

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