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# Epidemiology of Injuries in Stand-Up Paddle Boarding

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**Background:** Stand-up paddle boarding (SUP) is a recreational activity and sport that has grown exponentially, with participation increasing from 1.1 million in 2010 to 2.8 million in 2014 in the United States alone. Despite this growth in participation, SUP remains underresearched with regard to injury epidemiology.

**Purpose:** To investigate injury epidemiology (severity, location, type, mechanism) in SUP.

**Study Design:** Descriptive epidemiology study.

**Methods:** An open-source online survey was administered to active SUP participants internationally. The survey captured information relevant to demographics, participation, and injury history over the past 12 months.

**Results:** Of 240 participants included in the data analysis, 67.1% were males, and 54.6% were involved in competition. Participants spent a mean  $192.6 \pm 179.5$  hours participating in SUP per year, most commonly for fun and fitness (43.3%) at the beach or bay (63.0%). A total of 95 participants had sustained at least 1 injury. A total of 161 injuries were recorded, resulting in an injury rate of 3.63 (95% CI, 3.04-4.16) per 1000 hours of SUP. The shoulder/upper arm was the most frequently injured body location, accounting for 32.9% of all injuries, followed by the lower back (14.3%) and the elbow/forearm (11.8%). The most common injury types were to muscle/tendon (50.4%), joint/ligament (22.6%), and skin (14.2%). Endurance paddling was the most frequently reported mechanism of injury (34.5%), followed by contact with a paddler's own board (20.1%) and sprint paddling (9.3%). Key risk factors for sustaining an injury were age >46 years, competitive status, and participating for >4.8 hours/week, as well as using SUP for racing.

**Conclusion:** This is the first study to report injury epidemiology for SUP. It is evident that both sexes participate in SUP for fun, fitness, and competition. With regard to injuries, the shoulder, lower back, and elbow are the most injury prone; older age, competitive status, and longer hours of participation all influenced the chance of injury. Findings from this study provide the foundation for injury prevention strategies.

**Keywords:** SUP; stand-up paddle boarding; injury epidemiology; sport injuries

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Stand-up paddle boarding (SUP) is a recreational and sporting activity that has increased in popularity globally within the past decade. In the United States alone, the population of SUP participants has increased from 1.1 million in 2010 to 2.8 million in 2014.<sup>24</sup> This water-based activity is a mixture of surfing and paddling-based sports, whereby the rider paddles while maintaining balance by standing on a board. SUP is appealing to the participant as it is easy to learn, can be practiced on any body of water, including riding waves similar to surfing, and is reported to be an ideal activity for a full-body workout.<sup>11</sup>

SUP has been suggested as a means of balance retraining<sup>19</sup> and as a rehabilitation tool for strength and endurance training of the trunk musculature.<sup>22</sup> Despite the increase in popularity through recreational use or for rehabilitation purposes, minimal studies have validated the aforementioned

benefits of SUP. There are also no published studies identifying or addressing injuries in the sport of SUP.

Injury epidemiology has been researched in other water-based sports through the use of injury surveillance databases,<sup>8</sup> interviews,<sup>10</sup> and web-based online surveys.<sup>2,3,13</sup> Web-based surveys are widely used in the literature, as they have the potential to collect data quickly and are inexpensive to conduct. Web-based surveys also enable data to be collected from a wider geographic area.<sup>18</sup> Previous studies in similar water-based sports, such as surfing, kayaking, and canoeing, have found lacerations to be the most common injury type, and the shoulder or hand to be the most commonly injured location.<sup>1,3,17,20</sup> Consequently, it is hypothesized that the injuries sustained in the sport of SUP will closely mimic those identified in similar water-based sports.

The primary purpose of this study was to investigate injury epidemiology in the sport of SUP using an online-based survey. We envisioned that the information gathered from the survey will form the foundation for injury prevention strategies in the sport of SUP.

## METHODS

An online national survey was developed with a professional survey platform (Qualtrics). Research ethics approval was granted by the University Human Research Ethics Committee (RO 1540).

### Design

The survey consisted of 4 sections: (1) introduction and informed consent, (2) demographics and participation, (3) training and competition, and (4) injuries.

Section 1 provided background information on the purpose of the study and electronic informed consent. Participants were unable to access the survey unless they provided informed consent. Section 2 involved demographic and SUP participation questions. Questions regarding age, sex, and information as to how the participant was first introduced to SUP were retrieved in this section. Section 3 involved questions on SUP lessons and warm-up routines, and information regarding a participant's competitive involvement. Section 4 detailed injuries sustained while engaged in SUP. The participant was instructed to only provide information regarding SUP injuries in the past 12 months. As an attempt to gather data for multiple injuries at the same body location, the participant was able to provide information on more than one injury at the same location. Information regarding injury severity, location, type, and mechanism were collected for each injury identified. To determine injury type, 5 broad areas were offered to the participant: skin, bone, muscle/tendon, joint/ligament, and nerve injuries.<sup>3,13</sup> It needs to be emphasized that diagnosis of injury was self-reported.

### Participants

Individuals who had participated in the recreational activity or sport of SUP within the past 12 months were eligible

to participate in the survey. To ensure that the SUP population was well represented, all advertising of the survey reinforced that the participant did not have to sustain an injury in the past 12 months to participate in the study. A 12-month time frame has been used previously in retrospective epidemiology surveys.<sup>3,13,23</sup> This time frame has been shown to result in 100% recall of whether an injury occurred or not; however, it needs to be noted that as questions increase in detail, the ability of recall decreases.<sup>4</sup>

### Procedure

The survey was pilot tested by a group of experts in survey design, SUP, sports rehabilitation, and physical therapy (N = 11). This was to ensure face validity, and relevant questions were included. The survey became available online between January 19, 2016, and March 21, 2016. An electronic link to the survey was distributed to members of SUP organizations, including the international governing body, Stand Up Paddle Athletes Association (SUPAA). The survey was also advertised via social media outlets (Facebook, Instagram, and Twitter), and radio spots, as well as through online newsletter features. A summary of the survey advertisement and distribution is detailed in the Appendix.

### Injury Definitions

**Severity.** Injuries were recorded if a participant reported that he or she missed 1 or more days of work or SUP and/or received medical attention for the injury. Minor injuries that did not affect work or SUP or require medical attention were not included in the analysis. This classification system has been previously used in online surveys in water-based sports investigating injury epidemiology.<sup>13</sup>

**Incidence.** Incidence rate (IR) and incidence proportion (IP) were used to analyze participation distribution. Incidence rate was defined as the rate of injury per unit of exposure. It was calculated by dividing the total number of injuries by the total hours of SUP reported within a 12-month period; total hours were converted to 1000 (total number of injuries/1000 hours SUP). Incidence proportion directly measures the risk of injuries and was calculated by dividing the number of injured athletes by the total number of athletes at risk during a specified period (total injured SUP riders/total SUP riders).<sup>9</sup>

### Data Analysis

The data were analyzed using Statistical Package for the Social Sciences (SPSS, version 23.0).<sup>6</sup> Frequencies and descriptive statistics were used to summarize each variable. The chi-square test was used to determine differences between categorical variables. Independent *t* tests were used to determine differences between each continuous variable. Alpha was set at  $P < .05$  a priori to determine significance.

TABLE 1  
Participant Physiological Demographics<sup>a</sup>

	Total (N = 240)	Males (n = 161)	Female (n = 69)
Age, y	43.7 ± 11.7	44.1 ± 11.7	42.8 ± 11.8
Weight, kg	82.8 ± 23.2	88.1 ± 22.6	70.4 ± 19.5
Height, m	1.8 ± 0.1	1.8 ± 0.1	1.7 ± 0.1
Body mass index, kg/m <sup>2</sup>	26.6 ± 6.4	27.3 ± 6.6	25.2 ± 5.9
Time spent SUP, h/y, <sup>b</sup> mean ± SD (IQR) <sup>c</sup>	192.6 ± 179.5 (202.5)	200.3 ± 165.9 (195)	174.8 ± 208.0 (220)

<sup>a</sup>Values are given as mean ± SD. IQR, interquartile range; SUP, stand-up paddle boarding.

<sup>b</sup>Hours per year was determined by adding the total hours per week and weeks per year together.

<sup>c</sup>IQR was used, as this variable had a large standard deviation due to outliers in the data set.

## RESULTS

A total of 309 participants started the survey. Of these participants, 69 did not progress past the informed consent page or did not provide adequate information to be included in the data analysis and were excluded from analysis. Therefore, 240 participant data sets were included in the demographic and participation analysis. Ten participants did not answer the injury section, leaving 230 participants (74.4%) to be included in the injury analysis. Participation was worldwide, with the majority from Australia (67%), followed by the United States (21.7%) and Europe (3.9%).

### Physiological and Participation Demographics

As seen in Table 1, the majority of respondents were male (67.1%), and on average older (+2.9%, 44.1 ± 11.7 vs 42.8 ± 11.8 years), heavier (+20.1%, 88.1 ± 22.6 vs 70.4 ± 19.5 kg), and taller (+5.5%, 1.8 ± 0.1 vs 1.7 ± 0.1 m) than the females. Males also reported greater hours of participation (+12.7%) than the females. Details of SUP participation can be found in Table 2. Less than half (40.5%) of the SUP users reported performing a warm-up, which primarily consisted of a gentle warm-up, either static or dynamic. The majority of users used SUP as a means of fun and fitness (43.3%) and commonly used a beach or bay (63.0%). A high percentage of respondents considered themselves to be competitive SUP riders (54.6%), most commonly involved in local competition (67.2%).

### Incidence Rate and Incidence Proportion

Of the 230 eligible participants, 95 (41.3%) reported sustaining an injury requiring days off work or SUP, with a total of 161 injuries. The IR of all participants was calculated to be 3.63 (95% confidence interval [CI], 3.04-4.16) injuries per 1000 hours of SUP. The IR for recreational SUP riders was higher than for competitive riders, 4.67 (95% CI, 3.40-5.94) injuries per 1000 hours of exposure versus 3.29 (95% CI, 2.67-3.90) injuries per 1000 hours of SUP, respectively.

The IP for total injuries was calculated at 0.41 (95% CI, 0.35-0.47) injuries per SUP participant per year. Competitive SUP riders had a significantly ( $\chi^2 = 7.12$ ;  $P = .007$ ) higher IP of 0.49 (95% CI, 0.40-0.57) when compared with

recreational SUP riders, with an IP of 0.31 (95% CI, 0.25-0.44) (Table 3).

### Injury Location, Type, and Mechanism

**Location.** The shoulder/upper arm was the most frequently injured body location from SUP, accounting for 32.9% of all major injuries. The lower back and elbow/forearm were also frequently injured body locations, making up 14.3% and 11.8% of all major injuries, respectively. A summary of major injuries among all body locations is given in Table 4.

**Injury Type.** Of all the injuries, the most common type occurred in the muscle/tendon (n = 114, 50.4%) followed by joint/ligament (n = 51, 22.6%) and skin (n = 32, 14.2%). With regard to the shoulder, 76.6% of injuries at this location were to muscle/tendon. A comprehensive summary of injury types at each body location is shown in Table 5.

**Mechanism of Injury.** Endurance paddling was the most frequently reported mechanism of injury, accounting for 34.9% (n = 94) of all major injuries. The second most common mechanism of injury in SUP occurred after contact with the SUP rider's own board (n = 54; 20.1%). The remaining mechanisms were predominantly experienced while sprint paddling (n = 25; 9.3%), riding the face of a wave (n = 19; 7.1%), and from striking the sea floor (n = 16; 5.9%). Endurance paddling was responsible for the majority of injuries seen in the shoulder/upper arm and lower back, making up 51.5% and 48.6% of mechanisms, respectively. Mechanisms of injury at each body site are detailed in Table 6.

### Risk Factors

Several risk factors were identified in this study, with older SUP riders identified as having significantly ( $t = 3.3$ ,  $P < .001$ ) more injuries than younger participants (mean values, 46.7 vs 41.6 years of age). Among all 230 participants who completed the injury portion of the survey, there was no difference in the number of injuries between sexes ( $\chi^2 = 1.0$ ,  $P < .31$ ).

Competitive SUP riders were identified as having significantly ( $\chi^2 = 7.7$ ,  $P < .007$ ) more injuries than recreational riders (n = 64 vs 31). This may be a direct reflection of the hours spent performing SUP between the 2 groups.

TABLE 2  
Participation Demographics<sup>a</sup>

	n	%
SUP preparation		
Warm-up routine		
Yes	94	40.5
No	138	59.5
Type of warm-up <sup>b</sup>		
Gentle	58	36.3
Static upper/lower body	48	30.0
Dynamic upper/lower body	38	23.8
Ballistic upper/lower body	6	3.8
Aerobic	10	6.3
SUP background		
Introduction to SUP		
Personal interest	98	40.8
Family member	9	3.8
Friends	47	19.6
Transition from other water-based sport	86	35.8
Main use		
Surfing	68	28.3
Racing	58	24.2
Touring	10	4.2
Fun and fitness	104	43.3
Environment		
Beach/bay	148	63.0
River	28	11.9
Lake	28	11.9
Creek	20	8.5
Canal/dam	4	1.7
Harbor	7	3.0
Competitive involvement		
Recreational <sup>b</sup>	109	45.4
Competitive	131	54.6
Local competition	88	67.2
State titles	19	14.5
National titles	17	13.0
International titles	7	5.3

<sup>a</sup>SUP, stand-up paddle boarding.

<sup>b</sup>Static stretches involve holding a stretch position for 30 to 60 seconds; dynamic stretches involve moving parts of your body and gradually increasing reach, speed of movement, or both; ballistic stretches involve stretching the muscle to near its limit, then stretched further with a bouncing movement.<sup>7</sup>

<sup>c</sup>Recreational participants did not participate in SUP competitions. Competitive participants were those who indicated that they participated in local competitions, state titles, national titles, or international titles within the past 12 months.

Competitive SUP riders reported spending significantly ( $t = 6.38$ ;  $P = .01$ ) more time in the water (average, 253 h/y), while recreational riders spent an average of 112 h/y performing SUP. When comparing upper and lower body injuries, competitive SUP riders sustained significantly more upper body injuries compared with recreational SUP riders ( $n = 47$  vs  $17$ ;  $\chi^2 = 9.8$ ,  $P < .002$ ), whereas no significant differences were seen in the number of major injuries to the lower half of the body ( $n = 29$  vs  $16$ ;  $\chi^2 = 1.3$ ,  $P < .26$ ).

Participants reported using their stand-up paddleboard for fun and fitness (43.3%), surfing (28.3%), racing (24.2%),

TABLE 3  
Participant Injuries<sup>a</sup>

	Injury <sup>b</sup>			Incidence Rate (Total No. of Injuries/ 1000 h SUP)	Incidence Proportion (Total Injured SUP Riders/ Total SUP Riders)
	No	Yes	Total		
Recreational	68	31	99	4.67/1000 (3.40-5.94)	0.31 (0.25-0.44)
Competitive	67	64	131	3.29/1000 (2.67-3.90)	0.49 (0.40-0.57)
Total	135	95	230	3.63/1000 (3.04-4.16)	0.41 (0.35-0.47)

<sup>a</sup>Values in parentheses are 95% confidence intervals. SUP, stand-up paddle boarding.

<sup>b</sup>Values are reported as number of participants. An injury was determined if it resulted in days missed from SUP or work and/or required medical attention from a health care professional.

TABLE 4  
Location of Injuries and Comparison of Recreational  
and Competitive Stand-Up Paddleboard Riders

Site	Injuries		Recreational Injuries, n <sup>a</sup>	Competitive Injuries, n <sup>a</sup>
	n <sup>a</sup>	%		
Head/ face	8	5.0	5	3
Neck	6	3.7	3	3
Shoulder/upper arm	53	32.9	12	41
Elbow/forearm	19	11.8	4	15
Wrist/hand	3	1.9	1	2
Upper back	5	3.1	2	3
Rib	12	7.5	5	7
Lower back	23	14.3	7	16
Hip/groin/buttock	6	3.7	4	2
Knee	10	6.2	1	9
Shin/calf	4	2.5	2	2
Ankle/foot	12	7.5	6	6
Total	161	100	52	109

<sup>a</sup>Refers to the number of injuries.

and touring (4.2%). SUP riders who predominantly used their boards for racing were significantly more likely to sustain an injury ( $\chi^2 = 13.7$ ,  $P < .001$ ). Riders who performed SUP for the purpose of fun and fitness had a significantly lower numbers of injuries ( $\chi^2 = 19.4$ ,  $P < .001$ ).

## DISCUSSION

There are several key findings from this study: (1) high frequencies of shoulder, lower back, and elbow injuries; (2) high frequencies of muscular and joint injuries; (3) mechanism of injury is commonly due to endurance paddling; (4) increased risk of injury for competitive participants, those older than 46 years, and participants who use SUP for racing and surfing; and (5) almost 1 in every 2 SUP participants will sustain an injury every 12 months. To our knowledge, this is the first epidemiological study that has investigated injuries in the recreational and

TABLE 5  
Injury Type and Location of Injuries and Comparisons Between Recreational and Competitive Stand-Up Paddleboard Riders

Site	Type of Injury <sup>a</sup>	Injuries, n (%)		
		Total (n = 95)	Recreational (n = 31)	Competitive (n = 64)
Head/face	Skin	10 (71.4)	6 (75.0)	4 (66.6)
	Ear	1 (7.2)	1 (12.5)	—
	Eye	—	—	—
	Bone	3 (21.4)	1 (12.5)	2 (33.3)
Neck	Skin	1 (14.3)	1 (20.0)	—
	Bone	—	—	—
	Joint/ligament	1 (14.3)	1 (20.0)	—
	Muscle/tendon	5 (71.4)	3 (60.0)	2 (100.0)
Shoulder/upper arm	Nerve	—	—	—
	Skin	—	—	—
	Bone	—	—	—
	Joint/ligament	13 (20.3)	4 (28.6)	9 (18.0)
	Muscle/tendon	49 (76.6)	9 (64.3)	40 (80.0)
Elbow/forearm	Nerve	2 (3.1)	1 (7.1)	1 (2.0)
	Skin	—	—	—
	Bone	—	—	—
	Joint/ligament	2 (9.1)	—	2 (11.1)
	Muscle/tendon	16 (72.7)	3 (75.0)	13 (72.2)
Wrist/hand	Nerve	4 (18.2)	1 (25.0)	3 (16.7)
	Skin	2 (22.2)	—	2 (28.6)
	Bone	1 (11.1)	—	1 (14.3)
	Joint/ligament	2 (22.2)	1 (50.0)	1 (14.3)
	Muscle/tendon	3 (33.3)	1 (50.0)	2 (28.6)
Upper back	Nerve	1 (11.1)	—	1 (14.3)
	Skin	1 (10.0)	—	—
	Bone	—	—	—
	Joint/ligament	—	—	—
	Muscle/tendon	9 (90.0)	2 (100.0)	7 (100.0)
Ribs/sternum	Nerve	—	—	—
	Skin	1 (6.7)	1 (14.3)	—
	Bone	6 (40.0)	3 (42.8)	3 (37.5)
	Joint/ligament	5 (33.3)	2 (28.6)	3 (37.5)
	Muscle/tendon	3 (20.0)	1 (14.3)	2 (25.0)
Lower back	Nerve	—	—	—
	Skin	1 (3.1)	1 (8.3)	—
	Bone	—	—	—
	Joint/ligament	10 (31.3)	5 (41.7)	5 (25.0)
	Muscle/tendon	16 (50.0)	4 (33.3)	12 (60.0)
Hip/groin/buttock	Nerve	5 (15.6)	2 (16.7)	3 (15.0)
	Skin	3 (33.3)	1 (25.0)	2 (40.0)
	Bone	1 (11.1)	1 (25.0)	—
	Joint/ligament	1 (11.1)	—	1 (20.0)
	Muscle/tendon	3 (33.3)	1 (25.0)	2 (40.0)
Knee	Nerve	1 (11.1)	1 (25.0)	—
	Skin	—	—	—
	Bone	1 (6.7)	—	1 (9.1)
	Joint/ligament	11 (73.3)	3 (75.0)	8 (72.8)
Shin/calf	Muscle/tendon	3 (20.0)	1 (25.0)	2 (18.2)
	Skin	7 (70.0)	3 (100.0)	4 (57.1)
	Bone	—	—	—
Ankle/foot	Muscle/tendon	3 (30.0)	—	3 (42.9)
	Skin	6 (31.6)	2 (28.6)	4 (33.3)
	Bone	3 (15.8)	2 (28.6)	1 (8.3)
	Joint/ligament	6 (31.6)	3 (42.8)	3 (25.0)
	Muscle/tendon	4 (21.0)	—	4 (33.3)

<sup>a</sup>Skin injury included laceration or bruise; ear injury included ear drum burst; eye injury included eyeball damage; bone injury included fracture; joint or ligament injury included sprain, disc, cartilage damage, dislocation, and subluxation; muscle or tendon injury included strain, tear, and rupture; nerve injury included compression and stretch.

TABLE 6  
Site and Mechanism of Injuries

Mechanism of Injury	Site of Injury, n												Total	%	
	Head/ Face	Neck	Shoulder/ Upper Arm	Elbow/ Forearm	Wrist/ Hand	Upper Back	Ribs/ Sternum	Lower Back	Hip/ Groin/ Buttock	Knee	Shin/ Calf	Ankle/ Foot			
Acute noncontact injuries															
Paddle sweeping	—	—	3	—	1	—	—	3	1	2	—	—	10	3.7	
Sprint paddling	—	1	15	3	—	—	2	1	1	2	—	—	25	9.3	
Riding the face of a wave	3	1	1	—	—	—	1	3	3	4	1	2	19	7.1	
Performing turning maneuvers on the wave	1	1	6	—	—	—	—	2	—	2	—	1	13	4.8	
Transporting board	—	—	1	2	—	—	1	2	—	—	—	2	8	3.0	
Acute contact injuries															
Contact with own board	17	—	3	—	2	—	10	2	4	5	9	2	54	20.1	
Struck by other board riders	—	—	—	1	—	—	—	1	—	—	1	1	4	1.5	
Striking surface of water	—	—	1	1	—	—	—	—	—	—	—	—	2	0.7	
Striking sea floor	1	—	—	—	2	1	—	2	—	1	—	9	16	5.9	
Stepping on/off board	1	—	—	—	—	—	—	—	1	—	2	4	8	3.0	
Hit with paddle	—	—	1	—	—	—	—	—	—	—	—	—	1	0.4	
Encounter with marine life	—	—	—	—	—	—	—	—	—	—	—	1	1	0.4	
Overuse injuries															
Endurance paddling	1	3	35	16	5	8	3	17	1	1	2	2	94	34.9	
Other	1	1	2	2	—	1	—	2	1	2	1	1	14	5.2	
Total	25	7	68	25	10	10	17	35	12	19	16	25	269	100	

sporting activity of SUP. The aim of the study was to investigate injury severity, location, type, and mechanism in SUP with the use of a comprehensive online-based survey. Additionally, we explored participation demographics (SUP preparation, introduction to SUP, and competitive involvement) among SUP enthusiasts. This study was intended to build a foundation for injury prevention strategies in SUP.

It was hypothesized that the shoulder would be the most frequently injured body location in SUP because of its high usage with paddling, reflecting common injury trends seen in other aquatic sports such as surfing and kayaking.<sup>2</sup> It would appear that the results of this study support this hypothesis. We found that the shoulder/upper arm ( $n = 53$ , 32.9%), lower back ( $n = 23$ , 14.3%), and elbow/forearm ( $n = 19$ , 11.8%) were the most common locations of injuries among competitive and recreational SUP riders. This means that approximately 6 out of every 10 injured participants will suffer an injury to their shoulder/upper arm, lower back, or elbow/forearm. When relating these findings to other water-based activities, an injury epidemiological study by Furness et al<sup>3</sup> reported that the most common

body location in surfing injuries among Australian surfers was also the shoulder, accounting for 16.4% of all major injuries and 17.1% of all major injuries in competitive surfers. Fiore and Houston<sup>1</sup> investigated injury trends in the sport of whitewater kayaking and found that the upper extremity accounted for 61% of all reported injuries, with the shoulder accounting for half of these injuries. Our current study also identified the upper extremity as having a higher incidence, with 66% of all injuries occurring in this area. The activity requirements of SUP may influence the high number of upper limb injuries. As the upper extremities (hands and arms) operate the paddle, force is transferred from the legs, through the trunk, and finally to the upper limbs. The summation of force transfer may predispose the shoulder (muscles and joint) to increased mechanical loads. For this reason, it may also explain why almost half of all injuries were a direct result of paddling-related mechanisms (paddle sweeping, sprint paddling, endurance paddling). Of all the injuries, 34.9% were a consequence of endurance paddling. Although SUP has been shown to improve a participant's upper body strength and aerobic

and anaerobic fitness,<sup>21</sup> endurance and repetitive paddling increase a SUP rider's risk of sustaining an upper body injury. Further research that investigates endurance paddling and its correlation with overuse or chronic injuries in SUP is recommended.

Risk factors were also identified in the current study. Competitive SUP riders and participants who use their boards to race or surf were at the highest risk of suffering an injury. An association can be made with the level of competition and activity participation. It is assumed that a person who identifies as a competitive SUP rider is more often involved in SUP racing and is more likely to perform advanced activities such as SUP surfing, compared with a recreational user.

This study found competitive participants to have an IR of 3.29 injuries per 1000 hours of SUP, with an IP of 0.49 injuries per year. This means that almost half, or 1 in 2 competitive SUP riders, will suffer 1 or more injuries each year. These findings reveal that competitive riders are more likely to suffer an injury than competitive surfers.<sup>3</sup> When comparing these results with research in the sport of surfing, the IR is lower for competitive surfers, at 1.51 major acute injuries per 1000 hours of surfing and an IP of 0.42 major acute injuries per year.<sup>3</sup> These results were of interest to us, as surfing is considered a strenuous water sport with high physical demand.<sup>12</sup> One hypothesis is that surfers spend 35% of their time remaining stationary, 16% performing miscellaneous activities, and only 5% spent riding waves,<sup>12</sup> and therefore the time that the participant is exposed to high physical demand is reduced when compared with SUP riders, who are constantly moving. Conversely, the IP and IR for SUP appear to be substantially lower than for extreme water sports such as wind surfing (IP of 1.9), kite surfing (IR of 7 injuries per 1000 hours), and cable wakeboarding (IR of 12 injuries per 1000 hours).<sup>14-16</sup>

The present study also reported injuries to the lower back and elbow/forearm. Unlike previous studies in surfing and paddle-based sports, where injuries to the shoulder were revealed, lower back and elbow injuries had not been commonly reported. The difference may be a result of the physical demands and biomechanics of SUP. Future studies should investigate whether poor paddling techniques (improper sweeping and trunk rotation) poses a risk for injuries in the sport of SUP. It could be hypothesized that poor paddling technique may be a contributing factor in the relatively high incidence of elbow/forearm and lower back injuries in both recreational and competitive SUP riders. It also needs to be noted that more than half (59.5%) of the participants did not conduct a warm-up routine of any type prior to commencing SUP. In line with previous research supporting the efficacy of warm-up routines,<sup>5</sup> it could be hypothesized that a SUP-specific warm-up may reduce the frequency of injury.

This epidemiological study has provided a foundation for future studies in the sport of SUP. The investigation of sporting-related injuries builds a platform for injury prevention strategies for athletes, coaches, trainers, and health care professionals specializing in sports. As there is a paucity of published studies on the topic of SUP, the current study provides valuable information regarding

TABLE 7  
Clinical Applications<sup>a</sup>

Health care professionals treating SUP riders should:
<ul style="list-style-type: none"> <li>• Acknowledge that injury incidence is higher in both older (age &gt;40 years) and competitive SUP participants</li> <li>• Screen for ROM, length, strength, and endurance imbalances particularly in the shoulder, lumbar spine, and elbow</li> </ul>
SUP coaches/instructors should:
<ul style="list-style-type: none"> <li>• Examine a SUP rider's paddling technique while performing endurance, sprint, and paddle sweeping (particular attention to how force is transferred from lower limb, lumbar spine and trunk, to elbow and shoulder joints)</li> <li>• Ensure adequate rest and periodization principles (ie, altering training intensity and duration) are incorporated into training schedules to avoid overtraining</li> <li>• Develop a training program for athletes that addresses paddling technique, strengthening, and flexibility of the injury prone regions (shoulder, elbow, and back)</li> </ul>

<sup>a</sup>Clinical applications made as a supplement to the findings from the present study. They will aid in the management, treatment, and prevention of common injuries seen in SUP. Further research on SUP biomechanics and proper paddling techniques is highly suggested to validate current recommendations. ROM, range of motion; SUP, stand-up paddle boarding.

participation and injury epidemiology. We provide clinical applications for coaches, trainers, and health care professionals managing SUP participants (Table 7). Future studies need to investigate the biomechanics of SUP to determine ideal paddling technique.

There are several limitations of this study that need to be acknowledged. First, because the study design is a retrospective online survey, there was the possibility of memory bias, whereby participants could not accurately recall their injury and the details pertaining to a specific injury. An attempt was made to limit memory bias by using a 12-month time frame, as this has been shown to result in 100% recall of whether an injury occurred or not.<sup>4</sup> Second, it could be postulated that SUP riders who have experienced an injury were more likely to partake in the survey over uninjured SUP riders. To limit participation bias toward injured SUP riders, the advertisement statement specifically encouraged all SUP riders to participate in this survey, whether they had sustained an injury or not while performing SUP. Third, there was no formal evaluation of the injuries by qualified health professionals; therefore, the accuracy of injury type is uncertain and results should be viewed with care. Finally, the small number of participants in relation to the estimated participation rates (230 out of 2.8 million) provides a very small representative sample size, and it is not possible to extrapolate injury rates to the entire SUP population. Therefore, results of this study are specific to the current sample, and caution should be exercised when generalizing results to SUP participants outside of this study.

## CONCLUSION

To our current knowledge, this is the first epidemiological study to identify injury trends in the sport of SUP. This



study recruited SUP riders from around the world to partake in a comprehensive online-based survey. The findings of this study identified the shoulder/ upper arm, lower back, and elbow as the most commonly injured body locations. At each body location, injuries were most often seen in the muscle/tendon. Injuries most frequently occurred during endurance paddling or by contact with one's own board. The present study also identified risk factors associated with SUP. Participants who were older in age, competitive, and/or use their boards to race or surf were at increased risk of sustaining an injury. Finally, this research may aid in developing specific training programs and educational programs for novice and expert SUP riders. As SUP continues to increase in popularity, future studies on the biomechanics and physical demands required in this sport are encouraged to further improve the current knowledge base.

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## APPENDIX

### Stand-Up Paddle Boarding (SUP) Survey Advertisement and Distribution

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