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RESEARCH

Retrospective Analysis of Chronic Injuries in Recreational and Competitive Surfers: Injury Location, Type, and Mechanism

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Only two studies have reported on chronic musculoskeletal surfing injuries. They found over half of the injuries were non-musculoskeletal, but did not consider mechanisms of injury. This study identified the location, type, and mechanisms of chronic injury in Australian recreational and competitive surfers using a cross-sectional retrospective observational design. A total of 1,348 participants (91.3% males, 43.1% competitive surfers) reported 1,068 chronic injuries, 883 of which were classified as major. Lower back (23.2%), shoulder (22.4%), and knee (12.1%) regions had the most chronic injuries. Competitive surfers had significantly ($p <$ .05) more lower back, ankle/foot, and head/face injuries than recreational surfers. Injuries were mostly musculoskeletal with only 7.8% being of non-musculoskeletal origin. Prolonged paddling was the highest frequency (21.1%) for mechanism of injury followed by turning maneuvers (14.8%). The study results contribute to the limited research on chronic surfing injuries.

Keywords: surfing, aquatic risk management, injuries, water safety

Early research conducted by Nathanson, Haynes, and Galanis (2002) estimated there are 18 million surfers worldwide; however, current research now estimates this number to be approximately 37 million (Moran & Webber, 2013). The recreational activity and sport of surfing has grown dramatically since the 1960s, though scientific research has been poorly mirrored in comparison with most other mainstream sports.

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When reviewing an injury, it is important to consider the stage of injury (acute or chronic). Acute injury has been defined as a sudden onset of sharp pain or sudden impact that the person can relate to a specific situation, normally resulting in tissue damage in a localized region (Askling, Lund, Saartok, & Thorstensson, 2002). To date, there are less than 20 studies exploring acute injuries in both recreational and competitive surfers and although these studies exist, it is difficult to draw clear conclusions due to variations in research methodologies. Earlier findings have revealed high frequencies of lacerations mainly to the head and leg regions (Allen, Eiseman, Straehley, & Orloff, 1977; Barry, Kleinig, & Brophy, 1982) with more recent research reporting an increase in soft tissue sprains and strains to the lower body regions (Meir, Zhou, Gilleard, & Coutts, 2012; Nathanson, Bird, Dao, & Tam-Sing, 2007). Acute injury research has also revealed very low injury rates ranging from 2.2 to 3.5 per 1,000 hr of recreational surfing (Lowdon, Pateman, & Pitman, 1983; Nathanson et al., 2002; Taylor, Bennett, Carter, Garewal, & Finch, 2004) and slightly higher at 6.6 per 1,000 hr for competitive surfing (Nathanson et al., 2007).

If an acute injury is poorly rehabilitated or residual symptoms persist, it is believed the injury can predispose the person to re-injury at the same site (Heggie & Caine, 2012). Residual symptoms such as restricted joint range of motion may lead to muscle atrophy and increased compensatory stress on other joints resulting in further musculoskeletal damage (Heggie & Caine, 2012). Both re-injury and residual symptoms associated with an acute injury can lead to chronic injury (also known as repetitive strain or overuse injuries).

Chronic injury is often defined as persistent or episodic pain lasting more than three months (Jordan, Holden, Mason, & Foster, 2010). It can be a gradual onset of pain with no definitive mechanism of injury, or the result of an acute injury poorly rehabilitated with residual symptoms (Pinzon & Larrabee, 2006). The pathogenesis of chronic injury commences with muscle fatigue due to repetitive overload (tissues fail to adapt to increased loads), and may involve bone, ligament, and most commonly musculotendinous structures. The muscle unit then tightens and may undergo physiological changes which often results in muscle spasms and tissues shortening. This incidentally leads to muscle weakness, leaving the muscle prone to re-injury and establishing a cycle of tissue damage (Kannus, 1997). Chronic injuries outnumber acute instantaneous injuries in almost every athletic activity (Wilder & Sethi, 2004). Chronic injuries, however, do not result in sudden loss of function; they are generally under-reported and attract less medical attention than acute disabling injuries. When individuals present for treatment for chronic injuries, the problem is usually well established and can be difficult to manage (Pinzon & Larrabee, 2006).

A recent review of the literature identified only two studies that have analyzed chronic musculoskeletal injuries in a surfing population (Nathanson et al., 2002; Taylor et al., 2004). Nathanson et al., (2002) identified that approximately half of all chronic injuries were classified as an overuse syndrome involving the musculoskeletal system. Taylor et al., (2004) revealed similar results with approximately half of all chronic injuries reported having some form of musculoskeletal origin. Survey based data collection methods were used in both studies and the exact type of chronic injury was identified as either an overuse syndrome or a chronic injury of musculoskeletal origin. A limitation of both of these studies, however, was that chronic injuries were broadly categorized, and the type or origin (nerve, joint, or muscular) of injury was not identified. The mechanism of injury was briefly addressed; however, no clear data were available in either study.

Given the paucity of research investigating chronic musculoskeletal injuries in a surfing population and the significant increase in participation, the primary aim of this research project was to identify the location, type, and mechanisms of chronic injuries in a surfing population. We hypothesized that the lack of sudden acute injuries (Meir et al., 2012) in current research and high participation levels would result in higher frequencies of chronic musculoskeletal injuries compared with the current two studies. A secondary aim was to determine risk factors for chronic injuries in a surfing population.

Method

This was a cross-sectional descriptive survey design. Research ethics approval was attained from the Bond University Human Research Ethics committee (RO 1540). An internet survey was developed and used to allow for national data collection as the diverse coastal locations of surfers and the accessibility of the internet would allow for increased participation.

Data Collection

Survey Monkey was the tool used to construct and deliver the online survey. To participate, respondents had to be active surfers and have at least 12 months of experience; the survey was active online for five months.

The survey consisted of two primary sections. Section one had questions that included demographic information and participation levels. Section two included questions related to chronic injury for all the major regions of the body, and also incorporated injury type, mechanism, severity, and injury management. Chronic injury was defined as a condition that occurred over a period of time with gradual onset of symptoms that did not have to be attributed to one specific event that resulted in pain or discomfort (Pluim et al., 2009). For the injury to be classified as chronic, it needed to have been present for three months or more (Jordan et al., 2010). This included injuries where the severity may vary dependent upon the amount of surfing performed. For chronic injuries to be included, they had to be caused or aggravated by surfing. A participant could report a chronic injury if they were previously or currently suffering from symptoms.

To determine the severity, chronic injuries were classified as either minor or major. Previous research by Nathanson et al., (2002) used the terms minor or significant; however, to reduce confusion, the classification "significant" was replaced with "major." Major injuries required one day or more of time off work and/or surfing and/or the participant required treatment from a health professional. Minor injuries did not interfere with work, surfing, or involve treatment from a health professional.

Data Analysis

Descriptive statistics and frequencies were used to summarize each variable. Significant differences ($p < .05$) between groups within the sample were analyzed using independent *t* tests. For categorical variables, a Chi-square test of independence was used to determine differences between variables. All statistical analysis was completed using Statistical Package for the Social Sciences (Ver 20.0, Armonk, NY, USA).

Data were categorized manually where the option "other" had been filled out by the participant. This was applied for injury type and mechanism of injury and was performed by an experienced physiotherapist. Where there was no clarity to the type or mechanism of injury, the injury type was classified as "unspecified" and the mechanism was classified as "unknown."

Results

A total of 1,582 respondents commenced the survey; however, only 1,348 were included in the data analysis as 234 respondents were deleted due to incomplete data. A total of 1,231 (91.3%) males and 117 (8.7%) females were included in the data analysis. The overall mean age was 35.8 (*SD* ± 13.1; range 11–70) years, with a median of 35.0 years. Males were significantly older (t = 4.0, $p < .001$) compared with females (mean age 36.2 vs. 31.9 years). The mean hours surfed per week was 6.7 (± 5.6) for males and 7.3 (± 6.8) for females. Of the total 1,348 surfers, 581 had previously or were currently involved in competitive surfing locally, nationally, or internationally.

Of 1,348 (1231 male, mean age 36.2, *SD* ± 13.2, 117 female mean age 31.9, *SD* ± 11.1) surfers, 477 (35.4%) reported suffering from a chronic injury caused or aggravated by surfing. As more than one injury could be listed a total of 1,068 chronic injuries were reported.

Chronic Surfing Injuries by Location

Table 1 reveals the location and severity of both minor and major chronic injuries. It also reveals the distribution of chronic injuries for both competitive and recreational surfers. The lower back, shoulder and knee had the highest distributions of injuries representing 23.2%, 22.4% and 12.1%, respectively. Chi-square analyses were conducted to ascertain differences between minor and major injuries. The shoulder revealed a significance difference ($\chi^2 = 4.029$, $p = .045$) between the number of minor injuries ($n = 23$) compared with the number of major injuries ($n = 198$).

Chi-square analyses also revealed significant differences between recreational and competitive surfers where competitive surfers had significantly higher numbers of lower back ($\chi^2 = 10.989$, $p < .001$), head/ face ($\chi^2 = 5.953$, $p = .015$) and ankle/ foot injuries ($\chi^2 = 6.131$, $p = .013$). There was also a significant difference (t = 11.0, $p < .001$) between hours surfed for competitive versus recreational surfers (mean values 406.9 ± 343.7 vs. 228.7 ± 214.3 hr per year).

Chronic Surfing Injuries by Type

Table 2 reveals the location of injury with a categorical breakdown of the type of injury. To simplify the extensive amount of data, types of injuries were classified into broader terms. Injuries of joint origin represented 43.5% ($n = 528$), muscular origin 23.6% ($n = 286$), nerve origin 4.6% ($n = 56$), skin 0.5% ($n = 6$), bone origin 3.9% ($n = 47$) unspecified 16.2% ($n = 197$), and non-musculoskeletal origin 7.7% ($n = 94$).

Chronic Surfing Injuries by Mechanism

Table 3 represents the mechanisms associated with the location of chronic injury. Prolonged paddling had the highest total frequency for any mechanism of injury at

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Table 1 Location of Both Minor and Major Chronic Injuries and Comparisons Between Recreational and Competitive Surfers

				Recreational	Competitive
Site	Total (Major & Minor) n, (%)	Minor n, (%)	Major n, (%)	Major n, (%)	Major n, (%)
Lower back	224 (21.0)	19 (10.3)	205 (23.2)	95 (21.3)	110 (25.8)
Shoulder	221 (20.1)	23 (12.4)	198 (22.4)	110 (24.7)	88 (20.1)
Knee	129 (15.8)	22 (11.9)	107 (12.1)	53 (11.9)	54 (12.6)
Neck	102 (9.6)	13 (7.0)	89 (10.9)	49 (11.0)	40 (9.2)
Thoracic region	78 (7.3)	22 (11.9)	56 (6.3)	29 (6.5)	27 (6.2)
Head/face	77 (7.2)	19 (10.3)	58 (6.6)	24 (5.4)	34 (7.8)
Hip/groin	73 (6.8)	17 (9.2)	56 (6.3)	31 (7.0)	25 (5.7)
Elbow	56 (5.2)	18 (9.7)	38 (4.3)	24 (5.4)	14 (3.2)
Ankle/foot	55 (5.1)	9 (4.9)	46 (5.2)	18 (4.0)	28 (6.4)
Wrist/hand	42 (3.9)	20 (10.8)	22 (2.5)	10 (2.2)	12 (2.7)
Shin/calf	11 (1.0)	3 (1.6)	8 (0.9)	3 (0.7)	5 (1.1)
Total	1068 (100)	185 (100)	883 (100)	446 (100)	437 (100)

Table 2 Site and Types of Major Chronic Injuries

	Injury origin, n (%)							
Injury location	Non-musculoskeletal[1]	Skin origin[2]	Joint origin[3]	Muscular origin[4]	Nerve origin[5]	Bone origin[6]	Unspecified origin[7]	Total for locations
Head/face	94 (91.2)	4 (3.9)	-	-	-	1 (1.0)	4 (3.9)	103
Neck	-	-	55 (45.5)	31 (25.6)	4 (3.3)	-	31 (25.6)	121
Shoulder	-	-	96 (37.7)	120 (47.2)	2 (0.8)	-	36 (14.2)	254
Elbow	-	-	8 (20.5)	21 (8.3)	2 (5.1)	2 (5.1)	6 (15.4)	39
Wrist/hand	-	-	8 (36.4)	3 (13.6)	-	2 (9.1)	9 (40.9)	22
Thoracic	-	-	13 (23.6)	-	-	8 (14.5)	34 (61.8)	55
Lower back	-	-	148 (47.1)	70 (22.3)	48 (15.3)	12 (3.8)	36 (11.5)	314
Hip/groin	-	1 (1.4)	28 (40)	16 (22.9)	-	4 (5.7)	21 (30.0)	70
Knee	-	-	137 (85.6)	11 (6.9)	-	1 (0.6)	11 (6.9)	160
Shin/calf	-	1(10.0)	-	5 (50.0)	-	3 (30.0)	1 (10.0)	10
Ankle	-	-	35 (53.0)	9 (13.6)	-	14 (21.2)	8 (12.1)	66
Total types, n (%)	94 (7.7)	6 (0.5)	528 (43.5)	286 (23.6)	56 (4.6)	47 (3.9)	197 (16.2)	1,214

Notes. [1]Non-musculoskeletal origin refers to ear injuries including auditory exostosis and otitis externa, and eye injuries including pterygium and abscess. [2]Skin origin refers to lacerations which required greater than 3 months healing. [3]Joint origin includes osteoarthritis, discal injuries, dislocation, subluxation, cartilage injury, ligamentous injury, and bursitis. [4]Muscular origin refers to muscle overuse injury, tendon injury, and general muscle pain. [5]Nerve origin includes radiculopathy, sciatica, and nerve injury. [6]Bone origin includes bone injuries, fractures, spondylolithesis, and medial tibial stress syndrome. [7]Unspecified origin was designated to chronic injuries where the participant was unable to identify the type of injury.

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21.1%, followed by turning maneuvers at 14.8%. Trauma from the force of the wave only represented 1.5%. Environmental exposure which included prolonged exposure of the water, sun and wind represented 5.6% as a mechanism of chronic injury.

Key Risk Factors

The data analysis demonstrated older surfers (39.3 ± 12.0 vs. 33.9 ± 13.3 years) were more likely to sustain a chronic injury ($t = 7.6$, $p < .001$) while surfing. There was no significant difference ($t = 0.38$, $p = .11$) between prevalence of chronic injury and hours spent surfing (309.6 ± 272.0 versus 303.2 ± 301.3 hr/year).

With regards to mechanisms of injury, paradoxically there was a significantly ($\chi^2 = 4.9$, $p < .05$) higher likelihood of sustaining a chronic injury in surfers who did not complete aerial maneuvers (28.9% vs. 36.5%). There was a significantly ($\chi^2 = 4.5$, $p = .034$) greater number of chronic injuries (minor or major) in recreational surfers compared with competitive surfers ($n = 253$ vs. 224).

Chi-square analysis was performed for all lower limb injuries to determine whether there was a significant difference between chronic injuries to the front versus back leg. Surprisingly, no significant differences were found in the prevalence of chronic injuries between legs.

Discussion

The primary aim of this retrospective analysis was to identify the location, type, and mechanism of chronic injuries incurred while surfing. The high frequency of chronic injuries at the lower back (23.2%), shoulder (22.4%), and knee (12.1%) highlights the stresses placed upon these locations and provide further direction for chronic injury management and prevention.

The lower back had the highest frequency of injuries compared with any other region (23.2%). This study found that 25.9% of mechanisms of chronic lower back injuries were attributed to turning maneuvers. When the surfer is standing on the board, they are performing explosive turning, cutting, and twisting movements often combining the trunk movements of flexion and rotation. These explosive and combined movements may predispose the lower back to chronic injury.

Other explanations for the high frequency of chronic lower back injuries may include the large amount of time spent in the prone position. This study found that 38.5% of the mechanisms of chronic lower back injury were attributed to both prolonged paddling and lying on the surf board, both of which involve lying prone. The lumbar spine is predominantly responsible for flexion and extension movements. During extension, the facet joints (apophyseal or zygoapophyseal) of the lumbar spine are in a closed pact position (Magee, 2008). When paddling in the prone position, hyperextension is needed for three reasons: 1) it will lift the front of the board (nose) out of the water to enable paddling, 2) it will allow for an increased arm clearance when paddling, and 3) it will allow the surfer's head to be faced in the direction he or she is paddling. If a surfer lacks adequate extension in the thoracic and cervical spine, the lumbar spine may be subject to increased demands of extension and subsequently be injured.

The shoulder had the second highest frequency for chronic injuries; as a large portion of time is spent paddling, it is not surprising that this study

Table 3 Site and Mechanisms of Major Chronic Injuries

Mechanism of Injury	Head/ Face	Neck	Shoulder	Elbow	Wrist/ Hand	Upper-back	Lower-back	Hip/ Groin	Knee	Shin/ Calf	Ankle/ Foot	Totals: n, (%)
Prolonged environmental exposure[1]	68	-	-	-	-	-	-	-	-	-	-	68 (5.6)
Keeping head up while paddling	-	70	-	-	-	-	-	-	-	-	-	70 (5.7)
Prolonged Lying on the surf board	-	8	-	-	-	23	37	-	-	-	-	68 (5.6)
Prolonged sitting on board	-	-	-	-	-	-	14	15	-	-	-	29 (2.4)
Trauma from the wave	-	8	-	-	-	-	6	3	1	-	-	18 (1.5)
Prolonged paddling	-	-	160	16	4	38	42	-	-	-	-	260 (21.1)
High intensity paddling	-	-	85	7	2	16	-	-	-	-	-	110 (8.9)
Duck diving	-	-	36	4	5	-	-	6	5	1	2	59 (4.8)
Pushing down to stand up	-	-	49	8	16	-	-	-	-	-	-	73 (5.9)
Stand up phase	-	-	-	-	-	-	2	24	36	2	12	76 (6.2)
Performing turning maneuvers	-	16	-	-	-	8	53	25	61	3	16	182 (14.8)
Tube riding	-	-	-	-	-	-	-	7	16	1	-	24 (1.9)
Landing Aerials	-	-	-	-	-	-	3	3	16	-	9	31 (2.5)
Certain stances[2]	-	-	-	-	-	-	-	-	-	-	21	21 (1.7)
Unknown[3]	-	11	18	3	4	9	48	12	21	3	13	142 (11.5)

Notes. [1]Includes prolonged sun, wind, and water exposure. [2]For example, rolling a foot inwards to get more contact with the grip pad during barrel riding. [3]Includes any cause where the participant cannot identify one specific cause or provide alternative information revealed prolonged paddling (45.9%) as the leading cause of shoulder injuries. The shoulder muscles are used repetitively during paddling and can be subject to fatigue thus undergoing physiological changes resulting in shortening of the muscle units (Kannus, 1997). This process may result in muscular imbalance at the shoulder region and may provide an explanation as to why the shoulder area had the second highest frequency for chronic injury. The shoulder region also revealed a significantly higher number of major injuries compared with minor injuries. This highlights the severity of shoulder injuries as most require time off work, surfing or result in the surfer having to seek treatment from a health professional.

The knee region had the third highest frequency for chronic injuries, with the majority of injuries to the knee being of joint origin (85.6%) and 39.1% of the mechanisms associated with knee injuries were attributed to turning maneuvers. Turning maneuvers require a torsional movement through the entire body. The feet are fixed on a surface which is made stable by a surfer and the knee may be subject to rotational forces predisposing this region to injury.

Surfing now also incorporates aerial maneuvers; this requires the surfer to use the wave as a ramp and launch both body and board into the air, land back on the face of the wave and redescend (Everline, 2007). The rear knee is required to maintain an intense valgus position (stress on the inside of the knee) to keep the board under the foot. This study did not show a high frequency for aerial maneuvers as a mechanism for chronic knee injuries as this would more often be associated with acute injury. The results of this study further validate this as there was a significantly ($\chi^2 = 4.9$, $p < .05$) greater association between chronic injury and surfers who did not complete aerial maneuvers (28.9% versus 36.5%). This would be expected given those carrying chronic injury would perhaps be disinclined to complete such challenging maneuvers.

The results from this study reveal lower frequencies of non-musculoskeletal injuries (7.7%). These injuries were classified as auditory exostosis which involves bony outgrowths which protrude into the ear canal; otitis externa, which involves trauma to the epithelial lining of the ear canal; and pterygiums, which involve a clear growth of skin over the cornea. The current findings from this study highlight the musculoskeletal emphasis of chronic injuries within the surfing population. A possible explanation for the significant growth of chronic musculoskeletal injuries may be due to the change in board design and the changes in surfing style. Lighter boards have allowed for aggressive and radical maneuvers to be performed thus placing increased stresses on the musculoskeletal system.

Only two other studies have analyzed chronic musculoskeletal and non-musculoskeletal injuries in surfers (Nathanson et al., 2002; Taylor et al., 2004). Nathanson et al., (2002) revealed that the highest region of musculoskeletal overuse syndromes were located at the shoulder, followed by the back and knee at 18%, 16%, and 9% respectively. Taylor et al., (2004) reported that 19.9% of chronic injuries were represented in the spine region followed by the shoulder (10.3%) and the knee (8.2%).

Both studies revealed approximately half of the injuries were of non-musculoskeletal origin. Taylor et al. (2004) revealed that 45.8% of chronic injuries were due to environmental exposure. Nathanson et al. (2002) revealed that 21% of chronic injuries were either otitis externa or auditory exostosis and a further 12% were pterygium, cellulitis, and sinusitis.

To our knowledge no information for chronic injury risk factors exists in the sport of surfing. The results of this study revealed that older surfers (> 39 years) were more at risk for chronic injuries. Surprisingly, there was no significant difference between the number of chronic injuries and hours spent surfing. Surfers who had a competitive history had a significantly higher number of lower back, head/face, and ankle injuries. This may be due to the aggressive torsional movements when performing turning maneuvers especially as these surfers are more likely able to complete such difficult maneuvers. The increase in head/face injuries may be due to the significant increase in hours surfed by competitive surfers and therefore greater environmental exposure causing ear and eye conditions as previously discussed. This study also found a significantly greater number of chronic injuries (minor and major) for recreational surfers compared with competitive surfers. This is surprising given the maneuvers these surfers are performing; however, it may further reinforce the need to be well-conditioned for the sport of surfing to negate chronic injuries. Competitive surfers are more likely to be involved in training outside of surfing and aerobically and anaerobically more accustomed to the sport of surfing.

Previous research has shown that increased age and hours surfing, competitive status, and surfing larger waves (overhead or higher) increase the chance of acute injury incidence (Nathanson et al., 2007; Taylor et al., 2004). Comparisons are difficult to make as these risk factors are for acute injuries only.

A limitation of this survey is that the data gathered was retrospectively reported. Memory decay of the participant may result in poor or incorrect reporting of a previous injury (Jenkins, Earle-Richardson, Slingerland, & May 2002). Future surfing injury surveillance studies should consider prospective data collection methods where injuries are recorded at the time of the event. Another limitation of the study is that surfers who were already injured were possibly more likely to participate in the survey. To limit bias toward injured surfers, the advertisements clarified that all surfers were able to participate whether injured or not.

Conclusions

This appears to be the largest surfing specific survey which has included both recreational and competitive surfers conducted within Australia to date. Our findings will provide clinicians with fundamental information regarding injury prone regions specific to surfing. We were able to identify that the lower back, shoulder, and knee are the key regions where chronic injuries occur in surfers. The results of our research have identified an increase in musculoskeletal injuries along with providing insight into the mechanisms of injury related to specific body regions. Further, this research may aid in reducing the occurrence of injury through screening awareness and the use of sports-specific strength training and conditioning. Future studies which evaluate screening of the aforementioned injury regions in surfers may provide further information for more robust prevention measures to be developed.

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