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Injury patterns in competitive and recreational surfing: a systematic review

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Injury patterns in competitive and recreational surfing: a systematic review

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Resumo:

Introdução: O surf é uma atividade saudável, mas também física e mentalmente exigente e pode ser afetada por uma miríade de fatores meteorológicos e geológicos. A evidência científica sobre as diferenças entre as lesões de surfistas recreativos e competitivos parece ser escassa.

Objetivos: Esta revisão tem como objetivo identificar possíveis diferenças entre surfistas recreativos e competitivos no que respeita à frequência, severidade, possíveis fatores de risco e padrões fisiopatológicos das lesões. Pretende-se ainda identificar possíveis lacunas na evidência científica existente, emitir recomendações para a investigação futura e aconselhar estratégias de prevenção de lesões.

Métodos: Foi realizada uma pesquisa bibliográfica nas bases de dados MEDLINE/PubMed, SPORTDiscus e Web of Science para identificar estudos sobre lesões de surf. Para serem incluídos, os estudos deveriam reportar dados originais, especificar se estudavam surfistas recreacionais e/ou competitivos, fornecer informação sobre lesões agudas e/ou analisar dados relativos a essas lesões, seus fatores de risco, severidade e/ou preditores.

Resultados: Foram incluídos 17 estudos sobre lesões de surf e 16 estudos de caso ou séries de casos sobre mielopatia do surfista. A percentagem de surfistas recreativos que sofreu pelo menos uma lesão variou entre 31 e 35% num período de 12 meses e entre 88 e 100% durante a vida. Para os surfistas competitivos essas percentagens variaram entre 42 e 49% e entre 81 e 100%, respetivamente. O surf competitivo parece estar associado a maior risco de lesão o que poderá ser parcialmente explicado por mais horas de prática de surf, pela exposição a condições meteorológicas e geográficas mais adversas e pela execução de manobras de elevada exigência técnica. A idade mais avançada, menor experiência e história prévia de cirurgia parecem também ser fatores de risco para lesão. Lesões da pele, articulações e músculo que afetam os membros inferiores parecem ser os tipos mais comuns em ambos os tipos de surfistas. O contacto com o próprio equipamento parece ser o mecanismo de lesão mais habitual. A mielopatia do surfista é uma patologia aguda, potencialmente grave e que afeta primariamente indivíduos saudáveis e sem experiência prévia no surf.

Conclusões: Ser competidor, ter menor experiência de surf, idade mais avançada ou história de cirurgia prévia parecem ser fatores de risco para sofrer lesões no surf. É necessária uma maior homogeneização da metodologia nos estudos sobre estas lesões. São também necessários mais estudos prospetivos que avaliem os fatores de risco para contrair lesões durante a prática recreativa e competitiva de surf.

Palavras-Chave: Desportos, Desportos Aquáticos, Feridas e Lesões, Lesões Atléticas

Abstract:

Background: Surfing is widely regarded as a healthy but also physically and mentally demanding activity affected by a myriad of meteorological and geological factors, all of which can have impact in the rate and type of injuries sustained while surfing. There seems to be a shortage of evidence regarding the differences between recreational and competitive surfing injuries.

Objectives: This review aimed at identifying possible differences in injury rates, severity, patterns and risk factors, between recreational and competitive surfers. Furthermore, it presents research gaps and suggests recommendations for future injury research and prevention.

Methods: The databases MEDLINE/PubMed, SPORTDiscus and Web of Science were searched to identify published studies reporting rates, severity and/or anatomical patterns of surfing injuries. Studies were required to report original data, clearly specify if recreational and/or competitive surfers were included and provide information regarding acute surfing injuries and/or analyse data concerning those injuries, their risk factors, contributors and/or predictors.

Results: 17 studies regarding recreational and competitive surfers' injuries and 16 case-reports and case-series regarding surfer's myelopathy were included in the qualitative analysis. The percentage of recreational surfers sustaining at least one injury ranged from 31 to 35% over a period of 12 months and from 88 to 100% in lifetime while 42 to 49% and 81 to 100% competitors were injured over the same periods. Competitive surfers appear to have a higher injury risk that might be partly explained by having more hours of surf practice, being exposed to dangerous meteorological and geographical conditions and executing high-performance surfing techniques. Being older, having less surfing experience and prior surgical history could also be factors influencing the risk of injury sustainment. Both recreational and competitive surfers appear to more frequently sustain skin, joint/ligament and muscle/tendon injuries affecting the lower limbs caused by contact with their own equipment. Studies regarding surfer's myelopathy point to this being a rare but potentially devastating nontraumatic spinal cord injury that commonly affects otherwise healthy novice surfers.

Conclusions: Competitive status, less surfing experience, older age and prior surgical injuries might be risk factors for sustaining more injuries while surfing. The most common types, anatomical locations and mechanisms of injury seem to be similar between recreational and competitive surfers. There is a need for higher methodological homogeneity among surfing injury studies. Moreover, future research should focus on the prospective assessment of potential risk factors for both recreational and competitive surfing injuries.

Key words: Athletic Injuries, Sports Medicine, Water Sports, Wounds and Injuries

List of abbreviations:

MRI – Magnetic resonance imaging

OR – Odds Ratio

PRISMA - Preferred reporting items for systematic reviews and meta-analyses

STROBE – Strengthening the reporting of observational studies in epidemiology

SUP – Stand-up paddle

T2 – T2-weighted magnetic resonance imaging

tPA – Tissue Plasminogen Activator

WSL – World Surf League

Contents:

List of tables:

List of figures:

1. Introduction:

There are an estimated 37 million surfers worldwide[1] and the surfing industry attracts an increasingly higher number of new fans every day[2]. The growing popularity of surfing as a sport has turned it into a more mainstream activity, enjoyed by people of all standards[2] and this has contributed to its recent inclusion in the list of Olympic sports[3].

Even though the first cinematographic records of water board sports in Portugal date to 1927[4], Portugal's first substantial movement of surfing enthusiasts developed during the 80s and 90s. Over the last two decades, the Portuguese surfing community has increased significantly and the latest estimates suggest that there are approximately 200.000 Portuguese surfers[5]. Portugal's vast coast and favourable meteorological conditions offer a wide diversity of surf spots and great wave consistency that allow for surfing all year round. Easier access to technical material and the growing number of surf schools and clubs also help explaining the growing number of recreational and competitive surfers in Portugal. According to Pordata[6], between 1998 and 2017 the number of Portuguese federated surfers increased from 1026 to 2382 and, as of 2020, there are 73 clubs[7] and 259 surf schools[8] registered in the Federação Portuguesa de Surf (Portuguese Surf Federation). These numbers support the idea that there is a greater number of competitive Portuguese surfers, which may in turn make us suspect of an even greater increase of Portuguese recreational surfers.

Surfing is widely regarded as a healthy activity that not only contributes to a higher quality of life but also has both physical and psychological benefits[9,10]. Being a high intensity activity often regarded as very attractive for adrenaline-seeking people, surfing is also considered a mean to achieve personal balance and relieve stress[11]. Nonetheless, like other sports, it is not risk-free. In fact, surfing is a physically and mentally demanding activity[12] involving both aerobic and anaerobic performance[13] and affected by a myriad of meteorological (wind, waves, tides and currents) and geological factors (sea bottom, surf spot access), all of which can have significant impact in the rate and type of injuries sustained while surfing.

To our knowledge, the first epidemiological surfing studies were conducted during the 70s[14] and 80s[15]. Over the last two decades the scientific community has increased its interest in the sport of surfing and there has been a surge in studies regarding the physiological, pathological, social and even environmental aspects of surfing. Nevertheless, scientific evidence regarding surfing pathology appears to continue to be scarce, consisting mostly of case-reports, case series and cross-sectional retrospective studies based on data from medical records or surveys and therefore probably relies on limited and convenience samples. To our knowledge, most of the studies focus on acute and/or chronic injuries or surfing-related illnesses and address their pathophysiology, exploring possible mechanisms of injury that include geographical and meteorological conditions

(i.e. type of sea bottom, wave height, marine life) and surfing-specific manoeuvres and equipment. Given the apparent growth in surfing enthusiasts we should expect an increase in surfing-related scientific evidence focused on leisure or recreational surfing' injury risk factors and prevention but, as far as we know, there seems to be a shortage of evidence regarding the differences between recreational and competitive surfers' injuries and their specific risk factors and physiopathological mechanisms.

This review aimed at identifying possible differences in injury rates, severity, patterns and risk factors, between recreational and competitive surfers. Furthermore, it presents research gaps and recommends further topics for consideration that shall help formulating future injury prevention interventions.

2. Methods:

This systematic review was conducted in accordance with Preferred Reporting Items for Systematic reviews and Meta-analyses (PRISMA) statement guidelines[16] and the review question was formulated following the [PI(E)COS] model[17]. The protocol for the review was submitted for registration in PROSPERO[18] (Registration ID: 171601).

2.1. Search strategy

The databases MEDLINE/PubMed, SPORTDiscus and Web of Science were searched in March 2020 to identify published studies reporting injury rates, severity and/or anatomical patterns of surfing, longboarding, bodyboarding, stand-up paddle and tow-in surfing.

The following [PI(E)COS] question was formulated: Do surfers (P) who surfboard-ride recreationally (I/E), compared to competitive surfers (C) have higher injury rates and less severe injuries (O)?

The search strategy combined key terms from the PI(E)CO question, population AND (exposure OR comparator) AND outcome:

1) Population: surf, surfer, surfers, surfing, surfboard, wave-riding, wave riding, bodyboard, bodyboarding, paddle board, paddle boarding, stand-up paddle
2) Intervention/exposure and comparator: recreational, recreative, leisure, athlete, athletes, competitive, competition, contest
3) Outcome: body regions, pathologic processes, musculoskeletal system, signs and symptoms, musculoskeletal diseases, athletic injuries, wounds and injuries, wounds, injury, injuries, movement, emergency treatment, trauma

The following search strategy was used on MEDLINE/Pubmed: (surf OR surfer OR surfers OR surfing OR surfboard OR wave-riding OR wave riding OR bodyboard OR bodyboarding OR body boarding OR paddle OR boarding OR stand-up paddle) AND (recreational OR recreative OR leisure OR athlete OR athletes OR competitive OR competition OR contest) AND (body regions OR pathologic processes OR musculoskeletal system OR signs and symptoms OR musculoskeletal diseases OR athletic injuries OR wounds and injuries OR injury OR injuries OR trauma OR movement OR emergency treatment). The same search strategy was then used to search SPORTDiscus and Web Of Science databases. EndNote X9® was used to manage the retrieved citations.

2.2. Study selection

Table 1 depicts the inclusion and exclusion criteria.

Two reviewers independently applied the eligibility criteria and screened the studies for inclusion. A Microsoft Excel® spreadsheet was used to record decisions. Selection of studies was divided in three steps: 1) screening of titles; 2) screening of abstracts; and 3) screening of full texts. During the screening phases, the two reviewers were blinded to each other's decisions. After the two reviewers ended their selection, decisions were checked for agreement. Subsequently, the full text of potentially relevant studies was fully read and independently screened for the eligibility criteria. Discrepancies in the study selection (both after step 1 and step 2) were discussed with a third reviewer. Interrater reliability was assessed with Cohen's Kappa Coefficient using SPSS Statistical Package 26 (IBM Corporation, New York, United States of America).

Additional studies found by backward citation searching of existent reviews and included studies were also considered and independently screened for the eligibility criteria.

During the screening phase of our review it came to our attention that most of the excluded case-reports and case-series concerned surfer's myelopathy. Surfer's myelopathy appears to be a rare acute surfing injury affecting novice surfers which might explain the absence of studies with higher level of evidence. We opted to include such studies in order to address this type of acute injury in this review.

2.3. Assessment of methodological quality and evidence level

The methodological quality of included studies was assessed using the "Strengthening the Reporting of Observational Studies in Epidemiology" (STROBE) statement [19]. The 22-item checklist was created as a guide to improve quality of observational studies, namely, cohort, cross-sectional and case-control studies. As per Williams et al. and Olmos et al. [20,21] studies were categorised based

on the percentage of items of the STROBE checklists they fulfilled. Studies that fulfilled less than 50%, between 50 and 80% or more than 80% of items were classified as having poor, moderate or good quality, respectively.

Studies were classified for level of evidence in accordance with the guidelines from the Centre for Evidence-Based Medicine[22].

2.4. Data extraction

After the final selection of studies against eligibility criteria, data was extracted. One of the reviewers was responsible for data extraction while one other checked the extracted data. Discrepancies in the extraction process were discussed and resolved by consensus with a third reviewer. The extracted data from each study selected for analysis included: name of first author, title, publication year, country of the study, study design, individual and surfing demographics (years of experience, hours of practice and type of board used), type of surfboard-activity (recreational or competitive), type, rate and mechanisms of injury, body regions affected and potential risk factors for sustaining injuries. A Microsoft Excel® spreadsheet was used to extract and manage this data.

2.5. Data analysis

Original data was used every time it was reported in a study. When the study did not provide such data, the percentage of injured surfers as well as number of injuries per surfer were calculated, if the provided information allowed. If the studies provided separate data for recreational and/or competitive surfers regarding anatomical location and injury type, the absolute frequencies for each category were collected and then merged. Since there were differences in the method of reporting injury type and anatomical locations, broader categories were created. The four anatomical location categories were “Head and Neck”, “Torso and Pelvis”, “Upper limbs” and “Lower limbs”. As for type of injury, the six categories were “Muscle/Tendon”, “Joint/Ligament”, “Skin”, “Bone”, “Spinal cord and peripheral nerve” and “Other”. “Muscle/Tendon” category includes muscle strain, tear or rupture and tendon injury. “Joint/Ligament” includes ligamentous sprain, cartilage damage, discal injury, dislocation, subluxation, bursitis. “Skin and subcutaneous tissue” includes lacerations, burns, abrasions, contusion, bruising and hematomas. “Bone” includes fractures, avulsion and bone bruising. “Spinal cord and peripheral nerve” includes neural compression, nerve stretch or other nervous injury. The “Other” category includes pneumothorax, ear drum perforation and other acute ear injuries, eyeball and eye socket injuries, concussions, loss

of conscience and other brain injuries. In some cases, grouping of types of injuries was difficult given the disparity of injury categories through the eligible studies. In case of doubt, we opted to include the injuries in the broader category. For instance, when some studies grouped muscle and tendon in the same category and others grouped tendon with joint injuries, we opted to classify these injuries as “Muscle/Tendon” and “Joint/Ligament”, respectively.

3. Results:

3.1. Study selection

A total of 3110 records were identified through database searching. Five hundred and fifty-six records were identified through Pubmed, 564 through Web of Science and 1990 from SportDiscus. After duplicate removal, 2885 records were screened by title and abstract against eligibility criteria. When no abstract was available for screening, the studies advanced to full-text screening. 103 studies were included in the full-text analysis. At the end, 11 studies were included in the qualitative analysis. The reference lists of included studies as well as those of the retrieved reviews were used for backwards citation screening, retrieving an additional 931 studies. These studies were then screened against the eligibility criteria leading to the inclusion of an additional 6 studies. As stated before, 16 case-reports and case-series regarding surfer’s myelopathy were included in the qualitative analysis. In the end, 17 studies and 16 case-reports and case-series were included in this review. The PRISMA flow diagram (Figure 1) summarizes the study selection process and presents reasons for excluded articles.

The Cohen’s Kappa (k = .628, $p < .005$) rendered “moderate agreement” between reviewers.

3.2. Study characteristics

Table 2 illustrates the general characteristics of the included studies, such as study design, data collection method and context, sample size and characteristics, evidence level as well as methodological quality. Table 3 illustrates the studies’ sample demographics. For data regarding surfer’s myelopathy studies see section 3.7.

Most of the studies included in the qualitative analysis were published after 2010 with only one being published before 2000. Sixteen of the studies deemed eligible were cross-sectional retrospective and one was a cross-sectional prospective cohort study. Ten studies addressed both recreational and competitive surfers’ injuries while five reported data exclusively from competitive surfers and two from recreational surfers.

Most included studies regarding surfing injuries retrieved data from one single country. These included Australia (5 studies), Brazil (4 studies), Portugal (3 studies), Japan (1 study) and USA (1 study). Four studies included international data from 4 to 48 countries.

All but three of selected articles comprised data obtained from surveys. The shortage of studies with data from medical records can be explained by the need imposed by the review team for studies to specify whether they gathered information from recreational and/or competitive surfers. Since most of the articles that collect data from medical records did not assess competitive status, these articles were deemed ineligible.

Sample sizes varied greatly between studies, ranging from 32 to 1348 individuals. Eight studies had samples comprised of less than 100 individuals.

The average overall methodological quality of included studies was 75% (moderate).

3.3. Injury rates and risk factors

Information regarding injury rates, average injuries per athlete, incidence proportions and incidence rates can be found in table 4.

While most studies provided the percentage of injured surfers or at least enough data to calculate it, only six studies provided separate data for recreational and/or competitive surfers. The percentage of recreational surfers sustaining at least an injury ranged from 31 to 35% over a period of 12 months and from 88 to 100% in lifetime, while 42 to 49% and 81 to 100% competitors were injured over the same periods. Almost all elected studies provided enough data to calculate the number of injuries per surfer over the period in analysis but only seven studies provided specific data for recreational and competitive surfers.

Of the ten studies whose samples comprised recreational and competitive surfers' injury data, six addressed the possible impact of competitive status on surfing injuries. Furness et al. [1] provided separate incidence proportion and incidence rates for competitive and recreational surfers. In their work, the authors calculated an incidence proportion of 0.35 injured recreational surfers per total number of surfers and an incidence proportion of 0.42 injured competitive surfers per total number of surfers. The incidence proportion of competitive surfers was significantly higher than the incidence proportion of recreational surfers ($\chi^2 = 6.4$, $p < .001$). The incidence rates were 2.18 and 1.51 major injuries per 1000 hours of surfing for recreational and competitive surfers, respectively. The authors also found that competitive surfers sustained significantly more acute injuries. In 2017, Furness et al.[23] concluded that competitive SUP riders had significantly ($\chi^2 = 7.7$, $p < .007$) more injuries than recreational riders. Riders who performed SUP recreationally had a significantly lower incidence proportion than competitive SUP riders (0.31 vs 0.49 injured surfers per total number of

surfers, χ^2 = 7.12, p < .007). The incidence rate was higher for recreational surfers (4.67 vs 3.29 injuries per 1000 hours of practice). Meir et al. [24] concluded that those surfers competing at a national level were also significantly (p < .001) more likely to sustain an injury. Minghelli et al.[5] reported not only that competitor surfers had 1.81 more probability (OR; p = .002) of being injured but also that this probability increased with the number of training sessions. Surfers who trained three or more times a week had a 1.42 higher risk of injury (OR; p = .011) then those that trained twice or less. On the other hand, those who had surfed for less than five years had 1.65 (OR, p = .009) higher probability of having an injury compared with those who had surfed ten or more years. Nathanson et al.[25] concluded that surfers who self-rated as advanced had 1.6 (OR, 1.1-2.3) more probability of being injured when compared to surfers who self-rated as inexperienced or intermediate. Experts/professionals had 1.9 (OR, 1.1-3.4) more probability of sustaining an injury than inexperienced or intermediate surfers. Almeida et al.[26] reported that surfers with less experience sustained more injuries (r = -.189, p = .002).

Nathanson[25] found that surfing overhead or higher sized waves was associated with twice (OR 2.0; 1.3-3.3) the risk of injury when compared with surfing waist-high or lower-sized waves. Nathanson et al.[27] also found that surfing over a hard seabed was associated with a 2.6 (OR; 1.3-5.2; p = .007) higher probability of being injured when compared with surfing above a sand seabed and that there was a 2.4 (OR; 1.5 – 3.9; p < .001) higher probability of injury when surfing large versus small waves. Almeida et al.[26] concluded that injuries requiring medical attention occurred 2.13 (OR) times more frequently on major height waves while Meir et al.[24] stated that surfers surfing offshore reefs were more likely to injure themselves.

Studies by Furness et al.[23] and Nathanson et al.[25] addressed the possible role of age in surfing injuries. Furness et al.[23] stated that SUP riders older than 46 years had significantly (t = 3.3, p < .001) more injuries than younger participants (mean values, 46.7 vs 41.6 years of age) and Nathanson et al.[25] concluded that surfers aged 40 years or more had 1.9 (OR, 1.1-3.4) more probability of sustaining an injury than those with 19 years or less.

The only study[28] that explored the role of prior pathology in the risk of injury showed that surfers who had underwent surgery had significantly more injuries than those who did not (56.9% greater average number of injuries, CI 9.1% - 121.2%).

3.4. Injury severity

Table 4 shows severity data retrieved from the selected articles.

We found high heterogeneity in the way severity is reported among studies. While some studies described severity in number of days of surfing lost [15,29], others divided injury severity in terms of

need for medical care or hospitalization, or described the type of healthcare sought by injured surfers [9,25]. In some studies [1,15,25,27], the injuries were divided in categories (i.e. minor, moderate, severe) based on the need for medical intervention, time spent hospitalised or in a healthcare facility. In other cases [23,24], injuries were only recorded if severe enough to keep the surfer out of the water while recovering or healing the injury. In one study[24] injury severity was also assessed by the surfers' perceived outcome of injury, such as "Significant loss of income due to extended periods of recovery and/or rehabilitation".

3.5. Injury type and anatomical location

Figures 2 and 3 illustrate type and anatomical location of recreational and competitive surfers' injuries.

We found great variability in the description of injury type and anatomical location. As stated before, in an effort to better understand the pathological patterns of recreational and professional surfers, we gathered the available data in broader categories.

Seven studies[1,23,29–33] provided separate data for the type of injury suffered by recreational and competitive surfers. Data from these studies showed that the three most common types of injury for both competitive and recreational surfers are skin, joint/ligament and muscle/tendon injuries. Competitive surfers seem to sustain more skin (39%), joint/ligament (26%) and muscle/tendon (23%) injuries whereas recreational seem to sustain more of skin (56%), muscle/tendon (17%) and joint/ligament (17%) injuries.

Seven studies[1,23,25,29–32] provided separate data for the anatomical location of recreational and competitive surfers' injuries. After compiling these data, we found that most of competitive and recreational surfers injuries affect the lower limbs (47% and 43%, respectively). The second most commonly injured anatomical location for both groups were the upper limbs (24% and 21%, respectively).

3.6. Injury mechanisms

Only four studies provided separate data regarding the mechanisms of injury of recreational or competitive surfers. Three studies[9,25,30] regarding competitive surfers' injuries showed that the most prevalent mechanism of injury was contact with the surfers' own board, followed by performing manoeuvres, and contact with sea bottom. Júnior et al.[33] showed that contact with the surfboard was also the most prevalent mechanism of recreational surfers' injuries (26.2%) with

performing manoeuvres (22.1%), wave turbulence (18.9%) and contact with sea bottom (17.2%) also being common.

3.7. Surfer's myelopathy

See table 5 for a summary of surfer's myelopathy article's findings.

Our search retrieved 16 case-reports and case-series that concerned surfer's myelopathy. Even though we could not find enough information to draw conclusions on its prevalence this appears to be a rare condition. Nevertheless, given the severity of the impacts of this condition, we thought it was worth mentioning. The first nine cases were presented by Thompson et al[34] in 2004. To our knowledge, at least 59 new cases of surfer's myelopathy have been subsequently reported. The reported cases regard injuries sustained in 8 different geographical locations. Fifty-eight cases were from injuries sustained in Hawaii, three from South Korea and Six from the United States of America, Brazil, Taiwan, Indonesia, Portugal and Japan, with one case each. One case report did not specify the country of injury occurrence. Almost all cases involved novice surfers, the majority of whom were enjoying their first surfing lessons. The most commonly reported symptoms were low back pain, inferior limb weakness and sensory alterations, with the more severe cases often evolving to permanent anaesthesia, paralysis and loss of bowel and bladder control. There were changes in thoracolumbar spinal cord in almost all cases in which an MRI was obtained. Main findings include T2 hyperintensity of central spinal cord extending longitudinally through the affected segments with some cases showing restricted diffusion in diffusion-weighted imaging with apparent diffusion coefficient mapping.

4. Discussion:

The main objective of this review was to identify differences in injury rates and injury risk factors between recreational and competitive surfers.

The findings of this review support the idea that competitive surfing is associated with greater risk of injury since most of the studies that retrieved injury data from both competitive and recreational surfers report such trend. While several reasons could justify the increased risk of injury of competitive surfing, some of the findings from this review may help understand why competitive surfers seem to be more prone to injury. Both studies from Furness et al. [1,23] found that recreational surfers had lower incidence proportion and higher incidence rate than competitive surfers. This means that, while recreational surfers have a higher number of injuries per 1000 hours of surfing, they have a lower number of injuries per year. Therefore, even though they have a higher

tendency to injure themselves while surfing, they tend to injury less on a yearly basis because of spending less time surfing. When comparing elite recreational and competitive surfers, Santos[35] found that recreational surfers spent less time surfing which supports the idea that competitive surfers have higher levels of surfing practice even when considering top performers. While seemingly intuitive, the notion that increased surfing time leads to higher injury rates was also supported by the findings of Minghelli et al.[5]. Thus, it seems that greater number of hours of surfing can, in fact, be one of the main factors for the increased injury risk of competitive surfers.

Environmental and geographical conditions might also play a role in the increased rate of surfing injuries of competitive surfers. Surfing competition scores are partly based in the degree of commitment of athletes[36]. Commitment involves surfing the most critical or steeper sections of bigger and more powerful waves, often doing so in shallower waters, over a hard seabed. Thus, it is expected that competitive surfers train and compete in riskier contexts, often exposing themselves to hazardous geographical and meteorological conditions. Since the evidence found in the studies from Almeida et al.[26], Nathanson et al.[25,27] and Meir et al.[24] highlights the higher probability of injury associated with surfing large waves and over a hard seabed, it is expected that the higher injury rate of competitive surfers might be partly explained by the challenging geographical and environmental conditions in which they perform.

Paradoxically, Santos et al.[35] found that the majority of injuries in a sample of elite recreational and competitive surfers were sustained in waves of 1.5 meters or less. The author proposed that this might be due to surfers performing more challenging manoeuvres in these conditions. In fact, performing high-performance manoeuvres seems to play a role not only in competitive surfer's injury rates but also in the type and anatomical locations of the injuries sustained, as we shall discuss later. During competition, surfers are rewarded by performing innovative and progressive surfing techniques[36]. In the past two decades, this has translated in a shift towards aerial surfing performance. Aerial surfing involves projecting above the crest of the wave and landing with the surfboard, preferably in a way in which the surfer can keep his momentum. Nowadays, aerial surfing is arguably regarded as the cutting edge of surfing technique and given the degree of difficulty of these manoeuvres they are less commonly performed by the everyday recreational surfer. Furness et al.[1] reported that aerialists had a higher incidence proportion than overall surfers and that there was a significant increase in injuries ($\chi^2 = 10.5$, $p < .001$) in the group of surfers that were able to perform aerials. Inada et al.[32] also supported the influence of aerial manoeuvres in competitive surfing injuries by highlighting the high proportion of knee and ankle injuries due to this kind of manoeuvres. Hence, there is evidence to support the role of high-performance surfing techniques in competitive surfer's injuries.

Factors like age differences, comorbidity and physiological performance might also play a role in the injury rates and injury patterns of surfing. The findings of Furness et al. and Nathanson et al. point to higher rates of injury in older surfers while Bazanella et al. showed that surgery history was associated with a higher rate of injury. These factors may, in fact, increase the risk of injury, especially in recreational surfers, in whom we might expect a wider age span and possibly more comorbidities. From the findings of Almeida et al.[26] and Minghelli et al.[5] it seems that less surfing experience is also a risk factor to injury, so we could speculate if older surfers which start surfing later in life might be at higher risk of injury.

To our knowledge, some studies[13,37,38] have tried to address the differences in physiological performance between competitive and recreational surfers but not their influence in surfing injury. The findings of this review did not retrieve enough data to draw any conclusion on this regard.

Severity of injury appears to be poorly represented in the included studies and there is high heterogeneity of provided data. Furthermore, there seems to be some overlap between injury definition and severity. This may not only lead to bias in sample selection but could also ultimately lead to biased epidemiological findings. Likewise, the diversity of severity data in the reviewed articles prevented us to draw any conclusions on the possible differences between recreational and competitive surfers' injury severity.

After collating the data regarding injury type for recreational and competitive surfers, we found that the three most common types of injury for both these subgroups of surfers are skin, joint/ligament and muscle/tendon injuries. Even though we only considered data from seven studies in this analysis, the results seem to be consistent across all the studies reviewed. Burgess et al[9] identified abrasions and lacerations as the most common types of injury, comprising 55% of all injuries, while muscle/tendon, joint/ligament and skin injuries were the most common types of injury on both studies by Furness et al.[1,13]. Lacerations were the most common type of injury in Lowdon et al.[15], Minghelli et al.[5] and Nathanson et al.[25] studies, with contusions, sprains, dislocations and strains being the other usual types of injuries. However, there seem to be some differences between recreational and competitive surfers within each injury type, with a tendency for a higher rate of muscle/tendon and joint/ligament injuries in competitive surfers and skin injuries in recreational surfers. These differences might be explained by the additional physical demands of competitive surfing and, as stated before, by the influence of aerial manoeuvres performed by competitive surfers. Inada et al.[32] not only defined midfoot joint injuries as distinguishing of competitive surfing, but also reported the influence of aerial manoeuvres in knee medial collateral ligament injuries, which might explain the higher proportion of joint injuries of competitive surfers. The higher percentage of skin injuries in recreational surfers might be due to

a higher rate of falls and contact with a surfer's own equipment as this has been regarded as the most common mechanism of injury in the reviewed studies.

Our review found that most injuries sustained by recreational and competitive surfers affect the lower limbs. There is a higher disparity of results in studies concerning injury location. Furness et al.[1] reported ankle, shoulder and head/face to be the most common anatomical locations of injury for surfers and shoulder/upper arm, lower back and elbow/forearm for SUP riders[23]. Four studies[15,24,25,27] reported the head as the most commonly injured anatomical location while one other[5] reported an almost equal proportion of knee/leg, shoulder/arm and cranium/face injuries. The higher proportion of lower limb injuries in our findings might be explained by the fact that all studies included in the analysis were from warm-water countries were wetsuits are less commonly used. Surfing with boardshorts might expose surfers to a higher number of lower limb skin injuries. As previously mentioned, when considering competitive surfer's injuries, one possible explanation for the high prevalence of lower limb injuries are aerial manoeuvres. Hohn et al.[39] reported that the most common orthopaedical injuries of competitive surfers were to the knee, ankle and shoulder and denoted a shift in the location of these injuries associated with aerial surfing during the mid-2000s. The authors noted that before the popularization of aerials the most common injuries were to the shoulder which then significantly decreased (p = .047). Ankle injuries, which were uncommon, significantly increased (p < .001) after aerials became popular in competitive surfing. This could explain why competitive surfers have higher rates of lower limb injuries.

Contact with the surfers' own equipment seems to be the most prevalent mechanism of injury for both competitive and recreational surfers. In fact, contact with a surfer's own board was the most common mechanism of injury in all but two of the articles that provided data regarding mechanism of injury. The generalized use of surfboard leash prevents the surfer from losing his board during surfing but also poses a higher risk of injury by keeping the surfboard close to the surfer when he falls. The hard materials and sharp fins used in most boards have a high injury potential whenever contact with the board occurs. According to the data we retrieved, other common mechanisms of injury include surfing manoeuvres, contact with the seabed and water turbulence. As stated before, certain surfing manoeuvres, wave size and sea bottom seem to be factors that contribute to the pathophysiology of surfing injuries.

All studies found in our review describe surfer's myelopathy as a nontraumatic spinal cord injury that primarily affects otherwise healthy novice surfers, frequently in their first surf lessons. The most common symptoms are low back pain and paresthesia associated with progressive sensory and motor deficits that start within minutes to hours after beginning surfing practice. When Thompson et al[34] reported the first cases of surfer's myelopathy they proposed that these injuries resulted from spinal cord ischemia mainly based on characteristic spinal cord infarction from

imagiological findings and the absence of prior pathology. The authors postulated that prone lumbar spine hyperextension associated with surfing paddling probably led to spinal cord infarction by a variety of vascular mechanisms. Takakura et al[40] added that repetitive movements performed while trying to stand on the surfboard could also contribute to surfer's myelopathy's pathogenesis. The vascular mechanisms proposed by Thompson et al[34] included the vasospasm of the artery of Adamkiewicz, avulsion of perforating vessels or transient ischemia in areas of borderline perfusion. While these pathophysiological mechanisms were supported by other authors [41–45], alternative explanations have been debated such as fibrocartilaginous embolism and inferior vena cava obstruction[46]. Nevertheless, the absence of histopathological evidence prevents any definitive conclusions to be drawn.

Even though there is no evidence to support the effectiveness of the medical interventions being used in this condition, Freedman et al[47] proposed a set of alternatives for its management. These include emergent spinal angiography with superselective catheter tPA or nimodipine or, alternatively, intravenous tPA or placement of a lumbar drain to reduce cerebrospinal fluid pressure. Inducing hypertension (MAP > 85 mm Hg), considering a National Acute Spinal Cord Injury Studies (NASCIS) III methylprednisolone protocol and early admission in an intensive care unit are other proposed interventions. Nevertheless, it appears that despite the various types of therapeutic interventions, several patients show little or no improvement at all. Furthermore, it seems that there is a correlation between severity of symptoms at admission and clinical outcome, with patients presenting with American Spinal Injury Impairment Scale A or B having significantly poorer outcomes[41]. Thus, novice surfers and surf coaches should be aware of this condition and encouraged to cease any surfing activity and seek medical care if any of the aforementioned signs of symptoms arise. This awareness may lead to early recognition and prompt therapeutic intervention, which may in turn help attain better overall neurological outcomes.

The results from this review should be interpreted with caution given the limitations of data provided by the included studies. Sample size varied greatly among studies and was mostly selected by convenience. Data collection was almost always conducted by means of surveys which are known to introduce recall bias. Furthermore, there was high methodological variability among studies, with different injury definitions and descriptions. Injury severity was also poorly considered. Our decision of including only studies that clearly defined the competitive status of individuals being studied also excluded most of the studies that retrieve data from medical records which can lead to further bias since most of the diagnostics and injury descriptions are provided by the surfer himself and not validated by healthcare professionals.

5. Future interventions:

The overall injury rate of surfing is not negligible. The studies in this review showed an overall incidence rate that varied between 0.88 and 3.5 injuries per 1000 hours of surfing with a minimum of 30%[5] of surfers sustaining an injury over a period of 12 months. These numbers should encourage future risk reducing interventions. Some of these interventions may include training surfers, lifeguards, surf instructors and surf coaches on the most common surfing injuries and their primary management as well as preventive strategies. Novice surfers should also be taught protective measures in case of fall or imminent contact with their own or other surfer's equipment. We also propose that all surf schools and clubs have a first aid kit and that all surf coaches and surf instructors have basic life support training or at least a first aid qualification. These professionals should also be familiar with the signs and symptoms of surfer's myelopathy. Unexperienced surfers should be encouraged to use protective equipment and user-friendly material (i.e. softboards with rubber fins) given that the main mechanism of injury seems to be contact with surfer's own equipment.

In studies providing information on type of healthcare professional sought by injured surfers[9,31,35], the most commonly reported professionals were the physician and physiotherapist. Therefore, in locations where surfing is practiced, these professionals should be familiar with the risks associated with this activity not only to better inform their patients on surfing mechanisms of injury and injury prevention but also to provide the most adequate care. In the same way, emergency medicine clinicians practicing in these locations should also be familiar in the recognition and management of surfer's injuries, especially surfer's myelopathy.

Even though there is no evidence to support the effect of protective gear in competitive surfing injury reduction we believe that, given the higher risk associated with competitive surfing, the use of helmets should be encouraged at least in those surfers with prior injuries.

6. Future directions in research:

In order to better understand the pathology of surfing injuries, its potential risk factors and the differences between recreational and competitive surfing injuries, there is a need for greater uniformity of the methodological aspects of surfing investigation. As stated by Burgess et al.[9], this has been accomplished in other sports and activities like soccer, tennis, athletics, rugby and horse racing by the means of specialist consensus statements that define the concepts of injury and illness and provide methodological guidance for epidemiological studies. While we are aware of the

differences between these sports and surfing, we think that providing uniform guidelines for surfing injury investigation would be a great improvement in this field of research.

In our opinion, surfing injury definitions should not be based on the need for medical attention/care or time spent without surfing, as this necessarily introduces a certain bias in injury description and overall epidemiological data. Instead, as a mean to better define the outcomes of surfing injuries, these concepts should be used as descriptors of severity.

In accordance with what has been previously proposed by Furness et al.[1], we also believe that incidence rate and incidence proportion should be standard in surfing injury's studies as they provide valuable information for researchers, surfers and surf coaches.

Another perhaps more controversial topic that needs to be addressed, is the definition of what water board-sports are considered surfing. We included surfing, longboarding, bodyboarding, stand-up paddle and tow-in surfing in the scope of this review, but this is a rather debatable choice.

Competitive status should also be clearly assessed whenever possible as this could lead to a better understanding of both recreational and competitive surfing' injury trends and risk factors.

Finally, more prospective studies are needed in the field of surfing medicine as data gattered from retrospective survey-based studies is more prone to recall bias and studies from medical records are necessarily more inclined to retrieve data from more severe injuries. It would also be interesting to have further research focusing in the influence of surfing in the health status of specific populations like older surfers or individuals with prior comorbidities.

7. Conclusions:

Competitive surfers appear to have higher injury risk than recreational surfers. This higher risk of injury might be partly explained by competitive surfer's higher number of hours of surf practice, by their possible exposure to more dangerous meteorological and geographical conditions and by performing high-performance surfing techniques like aerials. Being older, having less surfing experience and/or having prior surgical history could also raise the risk of sustaining a surfing injury.

The most common types of injury for both competitive and recreational surfers are skin, joint/ligament and muscle/tendon injuries. Within each injury type, there is a higher percentage of muscle/tendon and joint/ligament in competitive surfers and a higher percentage of skin injuries in recreational surfers. Most injuries sustained by both recreational and competitive surfers affect the lower limbs. Contact with the surfer's own board is the most commonly reported mechanism of injury for both recreational and competitive surfers.

Surfer's myelopathy is a rare but potentially devastating nontraumatic spinal cord injury that commonly affects otherwise healthy novice surfers. Low back pain and paresthesias are the most

common symptoms and usually start within minutes to hours after initiating surf practice. Surfers, surf coaches and healthcare professionals should be aware of this condition in order to accomplish early recognition and prompt therapeutic intervention.

Surf coaches and instructors should be encouraged to have basic life support training or at least a first aid qualification. Clinicians practicing in locations where surfing is performed should be aware of the potential hazards of this activity in order to inform their patients about its risk and necessary precautions and act accordingly in the cases where healthcare assistance is required.

There is a need for higher methodological homogeneity between surfing injury studies. Moreover, future research should focus on the prospective assessment of potential risk factors for both recreational and competitive surfing injuries and the impact of surfing on certain populations like older and non-healthy individuals.

8. Appendixes:

Table I: Inclusion and exclusion criteria

Inclusion Criteria
Study with original data Study regards acute surfing injuries sustained in recreative and/or competitive surfing and includes and/or analyses data concerning those injuries Study regards acute surfing injuries sustained in recreative and/or competitive surfing and their risk factors, contributors, and/or predictors Study clearly specifies if recreational and/or competitive surfers were included
Exclusion Criteria
Study focuses solely on non-sea-related or non-wave riding sports or activities, namely, snow, river, lake or pool sports or activities Study focuses solely on any water activities propelled by a vessel or any motorized mechanism except tow-in surfing Study focuses solely on adapted surfing or disabled individuals Single case-reports or case-series, abstracts in conference proceedings, letters to editor or correspondence No full text available in English or Portuguese
Definitions
Surfing: includes surfing, longboarding, bodyboarding, stand-up paddle and tow-in surfing
Acute injury: Any physical complaint or manifestation experienced during surfing, irrespective of the need for medical attention or time loss from surfing or daily life activities

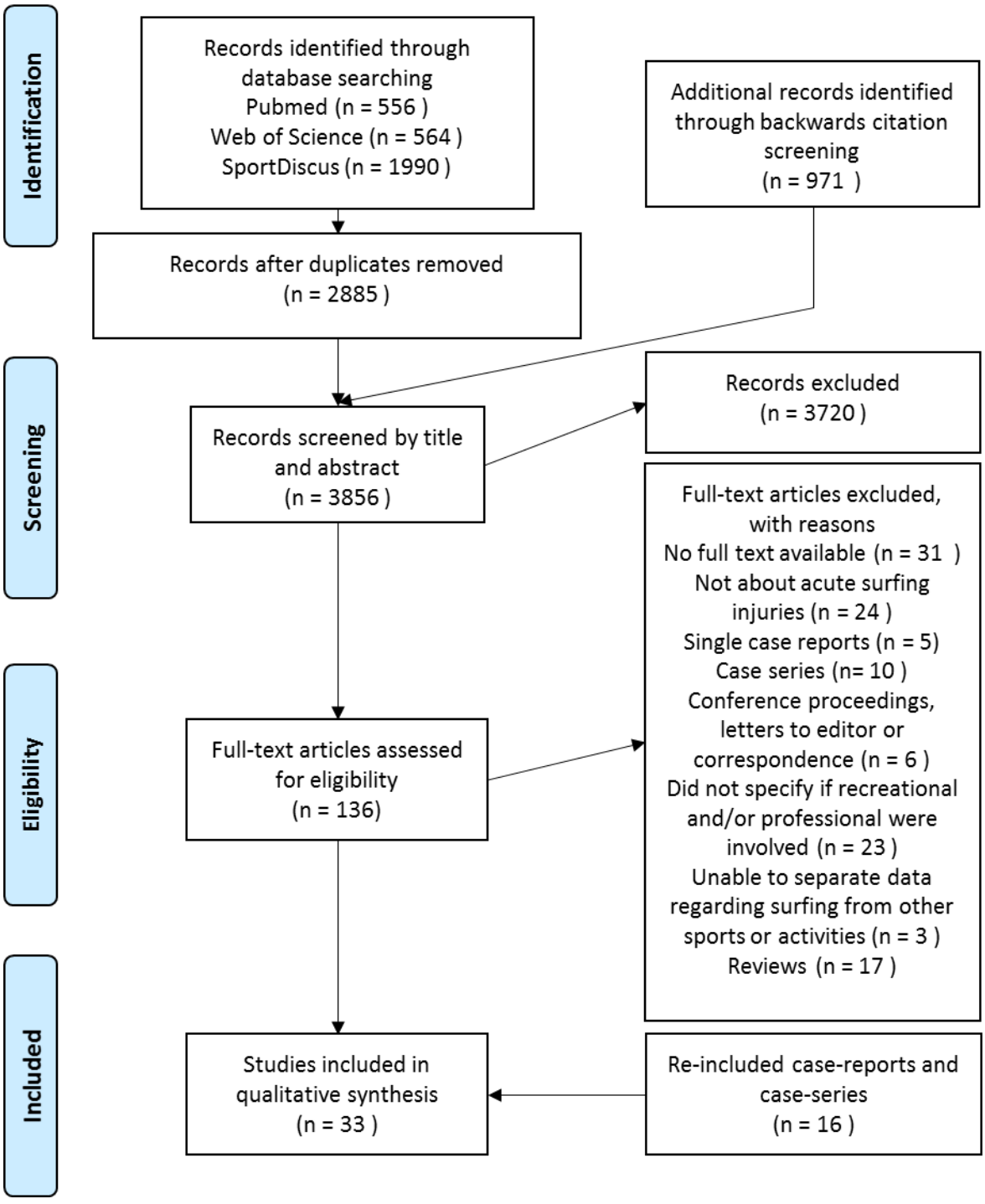

Figure 1: PRISMA[16] flow diagram

Table II: General characteristics of studies included in the review (N = 17)

Author (Year)	Title	Design	Data Collection Method	Context	Period of data collection	Number of participants	Evidence Level	Methodological Assessment
Almeida, J. A. et al. (2009)[26]	Contribution for the knowledge of surf acute injuries in Portugal	Cross-sectional Retrospective Cohort	Paper back survey	Surfers attending Portuguese beaches	4 months of 2009	151	3b	Moderate
Base, L. H. et al. (2007)[30]	Injuries among professional surfers	Cross-sectional Retrospective Cohort	Questionnaire by interview	Surfers competing in one phase of the Brazilian Professional Surfing Championship, Maresias Beach, São Sebastião, Brazil	June 25 to June 26, 2005	32	3b	Moderate
Bazanella, N. V. et al. (2017)[28]	Influence of practice time on surfing injuries	Cross-sectional Retrospective Cohort	Questionnaire by interview	Surfers from the Paraná Coast, Brazil	Unspecified	66	3b	Moderate
Burgess, A. et al. (2019)[9]	An Australian survey on health and injuries in adult competitive surfing	Cross-sectional Retrospective Cohort	Online survey	2014 Australian Surfing Titles, Coffs Harbour, Australia	1 to 31 August 2014	227	3b	Good
de Moraes, G. C. et al. (2013)[29]	Analysis of Injuries' Prevalence in Surfers from Parana Seacoast	Cross-sectional Retrospective Cohort	Paper back survey	Beaches of the seacoast of Paraná at the cities Guaratuba, Matinhos and Pontal do Paraná, Brasil	Not specified	60	3b	Moderate
Foo, P. et al. (2004)[31]	Surfing injuries in recreational surfers	Cross-sectional Retrospective Cohort	Written survey	Members of Australian surfboard riding clubs and surfers at beaches from Western Australia, Victoria, New South Wales and Queensland	May to July 2004	146	3b	Good
Furness, J. et al. (2015)[1]	Acute Injuries in Recreational and Competitive Surfers Incidence, Severity, Location, Type, and Mechanism	Cross-sectional Retrospective Cohort	Online survey	Australia	October 25, 2012 to March 25, 2013	1348	3b	Good
Furness, J. et al. (2017)[23]	Epidemiology of Injuries in Stand-Up Paddle Boarding	Cross-sectional Retrospective Cohort	Online survey	Australia (67%), United States of America (21.7%), Europe (3.9%).	January 19, 2016 to March 21, 2016	230	3b	Good
Hohn, E. et al. (2018)[39]	Orthopaedic Injuries in Professional Surfers: A Retrospective Study at a Single Orthopaedic Centre	Cross-sectional Retrospective Cohort	Medical records	Doctor W. G. K. (Official WSL specialist) Orthopedics Clinic	1999 to 2016	86	3b	Good

Table II *Cont.*

Author (Year)	Title	Design	Data Colection Method	Context	Period of data collection	Number of participants	Evidence Level	Methodological Assessment
Inada K. et al. (2018)[32]	Acute injuries and chronic disorders in competitive surfing: From the survey of professional surfers in Japan.	Cross-sectional Retrospective Cohort	Medical records	Data retrieved from medical personel in 50 contests of Japan Pro Surfing Tour (2009 to 2016) and one outpatient clinic (2010 to 2016)	2009 to 2016	Unspecified	3b	Moderate
Júnior, N. E. et al. (2013)[33]	Characteristics of training and injuries in amateur surfers	Cross-sectional Retrospective Cohort	Online survey	Brasil	January to March 2012	33	3b	Moderate
Lowdon, B. J. et al. (1983)[15]	Surfboard-riding injuries	Cross-sectional Retrospective Cohort	Written questionnaire	Surfers from Victorian Branch of the Australian Surfriders Association	March 1982	346	3b	Moderate
Meir, Rudi A. et al. (2012)[24]	An investigation of surf injury prevalence in Australian surfers: A self-reported retrospective analysis	Cross-sectional Retrospective Cohort	Online survey	Australia	Not specified	685	3b	Good
Minghelli, B. et al. (2018)[5]	Injuries in recreational and competitive surfers: a nationwide study in Portugal	Cross-sectional Retrospective Cohort	Questionnaire by structured interview	Portugal	2016	1016	3b	Good
Nathanson, A. et al. (2007)[27]	Competitive surfing injuries - A prospective study of surfing-related injuries among contest surfers	Cross-sectional Prospective Cohort	Medical records	Professional (22) and amateur (10) competitions in Hawaii, Australia, California, Tahiti, Argentina and East Coast of USA	March 1999 to September 2005	Unspecified	2b	Good
Nathanson, A. et al. (2002)[25]	Surfing injuries	Cross-sectional Retrospective Cohort	Online survey	Surfers from 48 countries - 76% USA, 6% Australia, 5% England, 2% New Zealand, 11% other coutries	May 1998 to August 1999	1348	3b	Good
Santos P. et al. (2014)[35]	Prevalência e incidência das lesões em surfistas de elite portugueses - Comparação entre competidores e não competidores	Cross-sectional Retrospective Cohort	Written survey	Top 30 surfers from Portuguese National Surfing Championship and top 30 portuguese free surfers acording to Associação Nacional de Surfistas (Nacional Surfers Association)	March to October 2012	60	3b	Good

Table III: Demographic characteristics of studies included in the review (N = 17)

Author (Year)	Mean Age (years)	Male/Female (%)	Recreational and/or Competitive
Almeida J. A. et al. (2009)[26]	31.46 ± 6.99	90/10	Recreational and competitive (Novice - 1.99%, Intermediate - 19.21%, Advanced - 39.07%, Professional - 39.74%)
Base, L. H. et al. (2007)[30]	16	100/0	Competitive
Bazanella, N. V. et al. (2017)[28]	26.16 ± 0.72	M and F (% not specified)	Recreational (65%) and competitive (35%)
Burgess, A. et al. (2019)[9]	35.0 ± 13.2	77/53	Competitive
de Moraes, G. C. et al. (2013)[29]	27 ± 6	100/0	Recreational (70%) and competitive (30%)
Foo, P. et al. (2004)[31]	30.05	84/16	Recreational
Furness, J. et al. (2015)[1]	35.8 ± 13.1	91/9	Recreational (57%) and competitive (43%)
Furness, J. et al. (2017)[23]	43.7 ± 11.7	70/30	Recreational (45%) and competitive (55%)
Hohn, E. et al. (2018)[39]	28.5	93/7	Competitive
Inada K. et al. (2018)[32]	Unspecified	Unspecified	Competitive
Júnior, N. E. et al. (2013)[33]	27.2 ± 6.2	100/0	Recreational
Lowdon, B. J. et al. (1983)[15]	21.8 ± 5.7	95/5	Recreational and competitive (beginner - 8%; average/competent - 30%; experienced or competitor - 62%)
Meir, Rudi A. et al. (2012)[24]	Mean 31.7 ± 12.9	85/14/1*	Recreational (72%) and competitive (28%)
Minghelli, B. et al. (2018)[5]	Mean 24.43 ± 11.98	84/16	Recreational (56%) and competitive (44%)
Nathanson, A. et al. (2007)[27]	Mean 23.6 ± 7	Unspecified	Competitive
Nathanson, A. et al. (2002)[25]	28.6 ± 10.6	90/10	Recreational and competitive (novice - 12%; intermediate - 36%; advanced - 37%; expert/professional - 15%)
Santos P. et al. (2014)[35]	27 ± 8.4	100/0	Recreational (50%) and competitive (50%)

*One percent transgender.

Table IV: Injury frequency and characteristics (N = 17)

Author (Year)	Injury definition (period of analysis)	Sustained at least one injury (%)	Injuries per surfer	Incidence rate and/or Incidence proportion	Severity	Injury Type (%)	Anatomical Location (%)	Injury Mechanism (%)
Almeida J. A. et al. (2009)[26]	Unspecified (Lifetime)	74.8%	Overall: 7.5	2.4 injuries/1000 surf sessions	No data	Laceration - 57.7% Contusion - 12.6% Joint sprain - 10.2% Fracture - 10.2% Other - 9.3%	Face - 25% Foot - 25% Hip/Leg - 11.5% Other - 38.5%	Own board - 53.3% Seabed/rocks - 19% Body motion - 16.9% Other - 10.8%
Base, L. H. et al. (2007)[30]	Unspecified (Lifetime)	100%	3.5	0.76 injuries/1000 days	No data	Cut-contusion - 33.9% Sprain - 25.9% Contusion - 14.3% Muscular strain - 12.5% Other - 13.4%	Lower Limbs - 57.1% Head - 20.5% Upper limbs - 11.6% Chest - 10.7%	Contact with surfboard - 47.3% Manoeuvre - 37.5% Seabed - 7.1% Other - 8.1%
Bazanella, N. V. et al. (2007)[28]	Unspecified (Lifetime)	90%	Overall: 2.7	No data	No data	Integumentary - 46.6% Muscle - 28.1% Ligament -14.6% Other - 10.7%	Lower limb - 44.9% Upper limb -20.2% Head - 18.5% Upper body - 16.3%	Drop and shock (with board) - 40.4% Animal - 40.4% Manoeuvre - 28.1% Paddling - 19.7%
Burgess, A. et al. (2019)[9]	Unspecified (Lifetime and current season)	81% in lifetime 58% in current season	No data	No data	100 (44%) surfers sought healthcare attention: Medical doctor - 35% Massage therapist - 7% Chiropractor - 13% Physiotherapist -10% Other - 35%	*Abrasion - 29% Laceration - 26% Cramping - 23% Joint sprain - 19% Muscle strain - 18% Ear injury - 15% Haematoma - 14% Other - 28%	*Lower Back - 20% Foot - 15% Knee - 14% Ankle - 13% Head - 11% Other - 58%	*Contact with surfboard - 24% Underwater turbulence - 19% Contact with reef bottom - 15% Barrel - 10% Other - 57%

Table IV *Cont.*

Author (Year)	Injury definition (period of analysis)	Sustained at least one injury (%)	Injuries per surfer	Incidence rate and/or Incidence proportion	Severity	Injury Type (%)	Anatomical Location (%)	Injury Mechanism (%)
de Moraes, G. C. et al. (2013)[29]	Unspecified (Lifetime)	100%	Overall: 6,45 Recreational: 6.6 Competitive: 6.2	No data	Period of absence from sport: None - 35% 1 to 6 days - 18% 1 to 3 weeks - 20% 1 to 3 months - 24% 4 to 6 months - 5% 7 to 9 months - 4% >10 months - 3% No answer - 5%	Contusion - 29% Burn - 23% Laceration - 23% Other - 25%	Legs - 26% Arms - 22% Feet - 20% Head/Neck - 16% Torso - 15%	*Contact with own board - 52% Maneuvers - 47% Marine animals - 27% Other injuries - 18%
Foo, P. et al. (2004)[31]	Unspecified (Past 2 years)	No data	9	No data	200 (15%) received treatment and were considered moderate/severe injuries Treatment Modality: Medical Doctor - 60.5% Physiotherapist - 16.0% Osteopath - 9.0% Other - 14.5	Lacerations - 52% Contusions - 36% Muscle - 4% Fractures - 4% Joint - 4%	Foot - 32.8% Leg below knee - 20.7% Leg above knee - 10.2% Other - 36.3%	No data

Table IV *Cont.*

Author (Year)	Injury definition (period of analysis)	Sustained at least one injury (%)	Injuries per surfer	Incidence rate and/or Incidence proportion	Severity	Injury Type (%)	Anatomical Location (%)	Injury Mechanism (%)
Furness, J. et al. (2015)[1]	Unspecified (Past 12 months)	Major injuries: Overall: 38% Recreational: 35% Professional: 42%	Major injuries: Overall: 0.5 Recreational: 0.5 Competitive: 0.6	Overall: IP - 0.38 (0.35-0.41) injured surfers/total surfers IR - 1.79 (1.67-1.92) major inj./1000h Recreational: IP - 0.35 (0.33-0.37) injured surfers/total surfers IR - 2.18 (1.98-2.42) major inj./1000h Competitive: IP - 0.42 (0.39-0.45) injured surfers/total surfers IR - 1.51 (1.35-1.67) major inj./1000h	Minor injury: any injury that did not interfere with work or surfing, or involve treatment from a health professional Major injury: any injury that required seeking medical treatment and/or prevented work or surf for at least 1 day	Muscle - 31.3% Joint - 28.7% Skin - 17.2% Other - 22.8	Ankle - 15.5% Shoulder - 14.7% Head - 14.5% Other - 55.3%	Major injuries data only: Striking sea bottom - 16.5% Own board - 16.1% Paddling - 10.9% Surface of sea - 10.6% Other - 45.9%
Furness, J. et al. (2017)[23]	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. (Past 12 months)	Overall: 41% Recreational: 31% Professional: 49%	Overall: 0.7 Recreational: 0.5 Professional: 0.8	Overall: IP - 0.41 (0.35 - 0.47) injured surfers/total surfers IR - 3.63 (3.04-4.16) inj./1000h Recreational: IP - 0.31 (0.25-0.44) injured surfers/total surfers IR - 4.67 (3.40-5.94) inj./1000h Competitive: IP - 0.49 (0.40-0.57) injured surfers/total surfers IR - 3.29 (3.04-4.16) inj./1000h	Injuries were recorded only 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.	Muscle/tendon - 50.4% Joint/Ligament - 22.6% Skin - 14.2% Other - 12.8%	Shoulder/upper arm - 32.9% Lower back - 14.3% Elbow/forearm - 11.8% Other - 41%	Own board - 20.1% Sprint paddling - 9.3% Riding wave - 7.1% Other - 63.5%

Table IV *Cont.*

Author (Year)	Injury definition (period of analysis)	Sustained at least one injury (%)	Injuries per surfer	Incidence rate and/or Incidence proportion	Severity	Injury Type (%)	Anatomical Location (%)	Injury Mechanism (%)
Hohn, E. et al. (2018)[39]	Unspecified (1999 to 2016)	No data	No data	No data	No data	† Knee: MCL Injury - 46% Meniscus Tear - 37% Chondromalacia - 11% Other - 39% Ankle: Sprain - 72% High ankle Sprain - 36% Ankle Fracture - 17% Anterolat. Impingem. - 14% Other - 17% Shoulder: Instability - 52% Rotator Cuff Tear - 42% SLAP Tear - 35% Subscapularis Tendon - 13% Chondromalacia - 10% Other - 15%	Knee - 28% Ankle - 22% Shoulder - 19% Back - 10% Hip - 10% Other - 13%	No data
Inada K. et al. (2018)[32]	Injury required medical evaluation or care (2009 to 2016)	No data	No data	6.6 injuries/1000h surfing	No data	Laceration/abrasion - 33.8% Ligament - 33.8% Other - 32.4%	Foot & Ankle - 40% Knee - 35% Shoulder - 6% Other - 19%	No data

Table IV *Cont.*

Author (Year)	Injury definition (period of analysis)	Sustained at least one injury (%)	Injuries per surfer	Incidence rate and/or Incidence proportion	Severity	Injury Type (%)	Anatomical Location (%)	Injury Mechanism (%)
Júnior, N. E. et al. (2013)[33]	Unspecified (Lifetime)	88%	3.7	No data	Injured at least once in lifetime and injury prevented surfing - 54.5% Injured at least once in lifetime but injury didn't prevent surfing - 33.3% Never injured - 12.2%	Laceration - 26.2% Contusion - 22.1% Burn - 20.5% Joint - 10.7% Other - 20.5%	No data	Board impact - 26.2% Manoeuvres - 22.1% Wave - 18.9% Sea bottom - 17.2% Marine animals - 10.7% Other - 4.9%
Lowdon, B. J. et al. (1983)[15]	Unspecified (Past 2 years)	Overall: 66%	Overall: 0.97	Overall: IR - 0.88 inj./1000h	Moderate to severe injuries: any injury that required either medical attention or days lost of surfing. Surfing days lost: 1 to 3 days: n = 138 4 to 14 days: n = 126 15 to 60: n = 35 More than 60 days: n = 9	Lacerations - 41% Sprains, dislocations, strains - 35% Fractures - 15% Other - 9%	Head - 37% Foot - 9% Low back - 7% Other - 47%	Own board - 45.4% Manoeuvre - 14.8% Rocks - 12.8% Other - 27%
Meir, Rudi A. et al. (2012)[24]	Injury that was severe enough to keep the individual out of the water while the injury healed/recovered. (Past 12 months)	Overall: 46%	Overall: 0.6	Overall: IR - 3.5 ± 3.4 inj./1000h	Needed to attend hospital - 19.3% Admitted requiring a stay of between 1 to 9 nights - 4% Lacerations identified as requiring stitches - 39.5% Perceived consequence: Significant loss of income - 6.6% Limitations with respect to job opportunities - 7.8% Medical costs not covered by a health fund or club insurance - 17.6% Limitations on normal recreational activities - 34.6% Early retirement from surfing - 1.9%	Unspecified - 32.6% Lacerations - 18.8% Soft tissue - 11.3% Fracture - 11.1% Other - 26.2%	Knee - 15.9% Ankle/foot - 14.9% Torso - 13.1% Shoulder - 13.1% Head - 12.8% Other - 30.2	No Data

Table IV *Cont.*

Author (Year)	Injury definition (period of analysis)	Sustained at least one injury (%)	Injuries per surfer	Incidence rate and/or Incidence proportion	Severity	Injury Type (%)	Anatomical Location (%)	Injury Mechanism (%)
Minghelli, B. et al. (2018)[5]	Any condition or symptom that ocurred as a result of surfing and had at least one of the following effects: Had to stop the surf activity for at least one day; did not have to stop, but had to change activity; sought advice or treatment from health professionals (Past 12 months)	Overall: 30%	Overall: 0.4	Overall: IP - 0.296 (0.268 - 0.324) inj./surfer/year, IR - 1.23 injuries/1000h	No data	Laceration - 23.5% Joint - 21.8% Muscle - 16.7% Low back pain - 12.9% Tendinitis - 10.1% Other - 15%	Knee/leg - 16.7% Shoulder/arm - 15.4% Cranium/face - 14.9% Lumbar spine - 14.9% Other - 38.1%	Impact of board - 27.1% Paddling - 17.9% Manoeuvre - 16.8% Animals/rocks/coral - 10.4% Other - 27.8%
Nathanson, A. et al. (2002)[25]	“Minor” and “Significant” injuries as stated in severity. (Past 5 years)	Overall: 69%	Overall: 0.9	No data	"Minor” injuries defined as those injuries in which the respondent was able to continue surfing. “Significant" injuries defined as those in which the respondent sought medical care, was unable to surf/work/attend school for more than 1 day or was hospitalized.	Laceration - 42% Contusion - 13% Sprain - 12% Other - 33%	Head/neck - 37% Lower extremity - 37% Trunk - 13% Upper extremity - 13% Systemic - 1%	Own board - 55% Sea floor - 17% Another surfers board - 12% Other - 16%

Table IV *Cont.*

Author (Year)	Injury definition (period of analysis)	Sustained at least one injury (%)	Injuries per surfer	Incidence rate and/or Incidence proportion	Severity	Injury Type (%)	Anatomical Location (%)	Injury Mechanism (%)
Nathanson, A. et al. (2007)[27]	Sudden-onset (acute) injuries that occurred during contest period. (Past 67 months)	No data	No data	IR - 13 inj./1000 h IR - 5.7 inj./1000 heats	"Significant" injuries prevented the athlete from surfing for 1 or more days, resulted in transportation. All other classified as "Minor injuries".	Sprain or strain - 39% Laceration - 30% Fracture or dislocation - 9% Contusion - 9% Other - 8%	Head/neck - 25% Upper extremity - 25% Torso - 11% Lower extremity - 39%	Own board - 29% Striking seafloor - 24% Own body motion - 16% Turbulence of wave - 12% Other - 14%
Santos P. (2014)[35]	Condition or symptom sustained during surf practice that prevented surfing and/or altered surfing activity and/or need healthcare professional assessment or care. (Past 8 months)	No data	Overall: 0.8 Recreational: 0.3 Competitive: 0.4	No data	Period of inactivity: 0 days - 17.4% 1 to 3 days - 13.0% 4 to 7 days - 21.7% 8 to 28 days - 26.1% More than 28 days - 21.7% Health care professional sought: Medical doctor - 40.0% Physiotherapist - 46.7% Osteopath - 6.7% Massage therapist - 6.7%	Joint - 34.8% Muscle - 21.7% Skin - 17.4% Other - 26.1%	Lower limbs - 47.8% Head and Neck - 21.7% Torso - 21.7% Upper limbs - 8.7%	Paddle - 18.2% Aerial - 18.2% Finalization - 13.6% Other – 50%

*Percentage of surfers that reported such injury types, anatomical locations and mechanisms of injury; †Percentage of surfers presenting with each injury type by anatomical location; IP – Incidence proportion; IR – Incidence rate

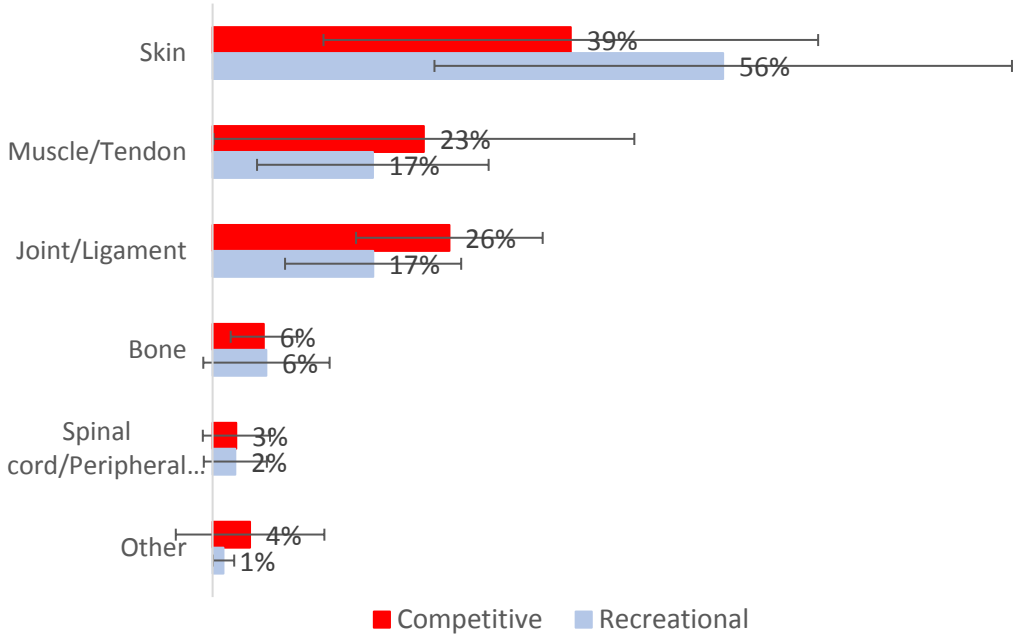

Figure 2: Injury type

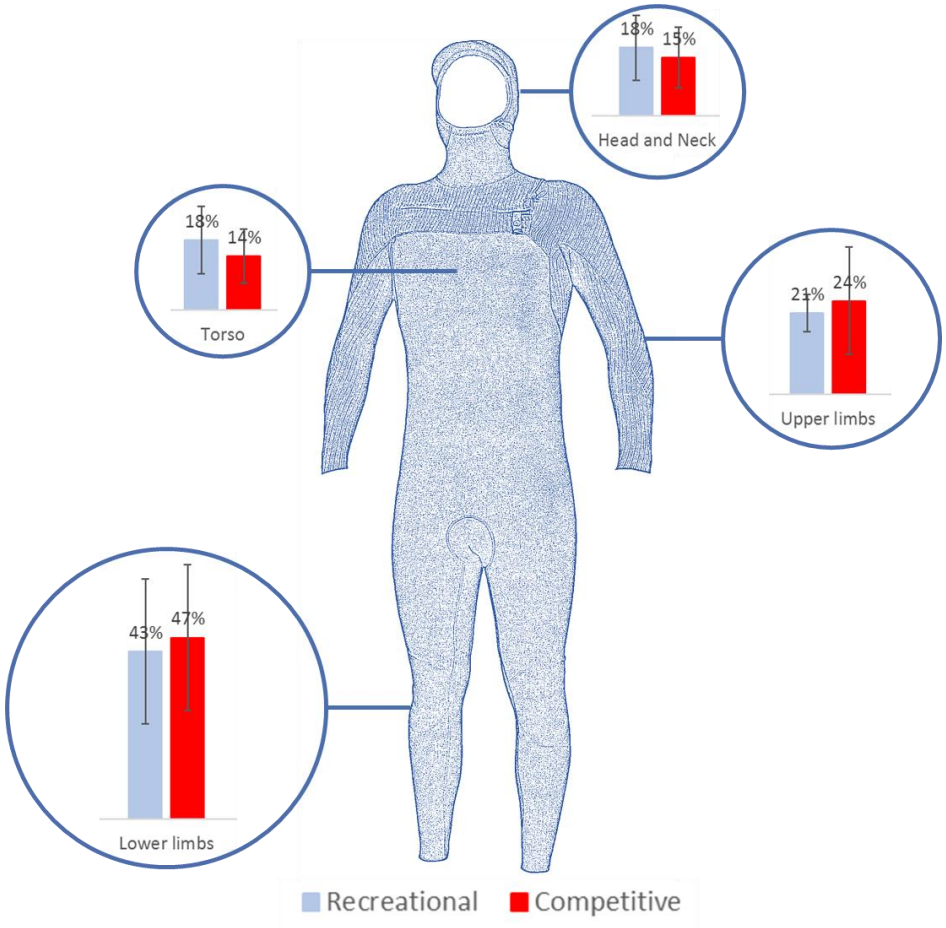

Figure 3: Anatomical locations of injury

Table V: Surfer's myelopathy case-reports and case-series data (N = 16)

Author (Year)	Title (Study design)	Evidence Level	Cases	Country of occurrence	Age (Years)	Sex	Context	Symptoms at presentation	AIS at admission	Follow-up
Aoki, M. et al (2013)[42]	Rehabilitation and long-term course of nontraumatic myelopathy associated with surfing (Case-report)	4	1	Hawaii	26	Male	Return to surfing after several years	Severe lower back pain about an hour after beginning surfing	AIS A with sensory and motor level at T12	AIS C
Avilés-Hernández, I. et al (2007)[46]	Nontraumatic myelopathy associated with surfing (Case-report)	4	1	Hawaii	37	Male	First surf lesson	Increasingly severe low back pain about 2.5 hours beginning of surf lesson and paresthesias	AIS A with sensory and motor level at T11	AIS A
Bakhsheshian, J. et al (2016)[48]	Teaching NeuroImages: Acute neurologic deficits due to surfer's myelopathy (Case-report)	4	1	Unspecified	32	Male	Novice surfer	Acute onset of low back pain	AIS C with sensory level T8, motor level at L2-S1 with loss of bowel and bladder control	AIS E within 3 days
Chang, C. et al (2012)[41]	Surfers' myelopathy: a case series of 19 novice surfers with nontraumatic myelopathy (Case-series)	4	19	Hawaii	From 15 to 46	14 males and 5 females	All novice surfers	Low back pain with "crack" or sudden "pop", cramps in buttocks and/or fatigue minutes to hours after surfing	8 AIS B, 5 AIS C, 3 AIS A and 3 AIS D	5 AIS A, 5 AIS D, 4 AIS B, 3 AIS E and 2 AIS C
Choi, J. et al (2018)[43]	Surfer's Myelopathy: Case Series and Literature Review (Case-series and literature review)	4	3	South Korea	19, 21 and 30	3 males	All in first surf lesson	Back pain, paresthesias, rapidly progressive loss of leg strength after first surfing lesson	1 AIS A, 1 AIS B and 1 AIS D	2 with almost no recovery, 1 almost fully recovered within 1 month
Dhaliwal, P. et al (2011)[49]	An unusual case of myelopathy: surfer's myelopathy (Case-report)	4	1	Hawaii	29	Male	First surf lesson	Lower back spasm and progressive lower extremity weakness. Completely paraplegic after 30 minutes.	AIS A	AIS B within 1 week

Table V *Cont.*

Author (Year)	Title (Study design)	Evidence Level	Cases	Country of occurrence	Age (Years)	Sex	Context	Symptoms at presentation	AIS at admission	Follow-up
Freedman, B. et al (2016)[47]	Surfer's Myelopathy: A Rare Form of Spinal Cord Infarction in Novice Surfers: A Systematic Review (Case-report and systematic review)	4	1	Hawaii	19	Male	First surf lesson	Acute onset of low back spasms and pain halfway through surf lessons	AIS A with sensory level at T11	AIS A within 4 years
Karabegovic, A. et al (2011)[50]	Surfer's myelopathy: case report and review (Case-report and literature review)	4	1	Indonesia	25	Male	First surf lesson	Low back pain, bilateral lower extremity weakness and paresthesias 1 hour after surf lesson	AIS C	Partial recovery
Lieske, J. et al (2011)[44]	Surfer's myelopathy-demonstrated by diffusion-weighted magnetic resonance imaging: a case report and literature review (Case-report and literature review)	4	1	USA	15	Female	Surf camp	Acute-onset low back pain and bilateral inferior limb paresthesias and paralysis 2 hours after	AIS C	AIS D after rehabilitation
Lin, C. et al (2012)[51]	Surfer's myelopathy (Case-report)	4	1	Taiwan	19	Male	First surf lesson	Low back pain, muscle weakness and decreased sensation of lower limbs after surf lesson	Unspecified	Unspecified
Nakamoto, B. et al (2013)[52]	Surfer's myelopathy: a radiologic study of 23 cases (Case-series)	4	23	Hawaii	Average 26.3 ± 7.4	19 males and 4 females	Surfing	22 presented with acute back pain associated with paraparesis while surfing	5 AIS A, 3 AIS B, 5 AIS C, 9 AIS D and 1 AIS E	Approximately 65% showed no improvement
Scatchard, R. et al (2018)[45]	A case report: Paediatric surfer's myelopathy (Case-report)	4	1	Portugal	8	Female	First surf lesson	Lower back and inferior limb pain and progressive inferior limb muscle weakness after 20 minutes	AIS A	AIS A
Shuster, A. et al (2011)[53]	Surfer's myelopathy -an unusual cause of acute spinal cord ischemia: a case report and review of the literature (Case-report and literature review)	4	1	Hawaii	23	Male	First surf lesson	Acute back pain and gradual weakness and loss of sensation of inferior limbs	AIS with sensory level at T10	Unspecified

Table V *Cont.*

Author (Year)	Title (Study design)	Evidence Level	Cases	Country of occurrence	Age (Years)	Sex	Context	Symptoms at presentation	AIS at admission	Follow-up
Takakura, T. et al (2013)[40]	Complete paraplegia resulting from surfer's myelopathy (Case-series)	4	3	2 in Hawaii and 1 in Japan	24, 25 and 31	2 males and 1 female	2 surfing (not first time) and 1 in first surf lesson	Back pain, paresthesias, inferior limb weakness 60 to 90 minutes after starting surfing	3 AIS A	3 AIS A
Teixeira, S. et al (2016)[54]	Imaging features and differentials in surfer's myelopathy: a case report (Case-report)	4	1	Brazil	23	Female	First surf lesson	Acute rapidly progressive lower extremity paraplegia, parestesia and anaesthesia and low back pain 2 hours after surfing	AIS B with sensory level at T11-T12	AIS C within 21 days
Thompson, T. et al (2004)[34]	Surfer's myelopathy (Case-series)	4	9	Hawaii	Average 25 (range, 21-30)	8 males and 1 female	None had prior surfing experience	Back pain (9), paraparesis (8), urinary retention (8), hypesthesia/hypoalgesia (3), hyperesthesia (2) and paraplegia (1).	8 AIS D and 1 AIS A	At discharge 4 had mild weakness without sensory deficits, 3 had complete recovery, 3 had residual urinary retention and 1 remained paraplegic.

AIS – American Spinal Injury Impairment Scale

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