Gradual-Onset Surfing Injuries in New Zealand: A Retrospective Epidemiological Study

Debbie Remnant

Declaration

Name of candidate: Debbie Remnant

This thesis entitled “Gradual-Onset Surfing Injuries in New Zealand: a retrospective epidemiological study” is submitted in partial fulfilment for the requirements for the Unitec degree of Master of Osteopathy.

Principal Supervisor: Catherine Bacon
Associate Supervisor: Robert Moran

Candidate’s declaration
I confirm that:
• This thesis represents my own work;
• The contribution of supervisors and others to this work was consistent with the Unitec Regulations and Policies.
• Research for this work has been conducted in accordance with the Unitec Research Ethics Committee Policy and Procedures, and has fulfilled any requirements set for this project by the Unitec Research Ethics Committee.

Research Ethics Committee Approval Number: 2015-1032

Candidate Signature: .................................................. Date: .....................

Student number: 1407061
Acknowledgements

I would like to thank my family and friends who held my hand along this journey and surfed, laughed, danced, ate donuts and painted with me; those who proof read, fed me, listened and hugged me; and those who provided sanctuaries for me while I endured this incredible experience.

A special thanks to my family, especially my mum and dad, as well as my sisters, their husband and their rug-rats, who have provided endless amounts of unconditional love and tremendous support for me. Thank you also to my classmates, tutors, Clinic 41 crew and Onslow team success who saw the daily state of it; and my salty friends who knew the best medicine was to take me to the water.

Thank you to Brett Beamsley for advertising the survey with Swellmap; Jason Falconridge at O’Neill for the wetsuit sponsor; the Todd Foundation for their research grant; and our Australian associate supervisors, Dr James Furness (Bond University), Assoc Prof Mike Climstein (The University of Sydney) and Prof Wayne Hing (Bond University), for providing the basis for the questionnaire and helpful suggestions about studydesign.

An enormous thank you to my supervisors, Dr Catherine Bacon and Rob Moran, who have nurtured me through this whole experience, have shared endless amounts of knowledge and wisdom, and have supported me beyond my expectations.

And lastly, but most importantly, a huge thank you to the New Zealand surfing community, especially all the surfers who completed and shared the survey, for their overwhelming support that made this project memorable.
# Table of Contents

Declaration........................................................................................................................................ii

Acknowledgements ..........................................................................................................................iii

Table of Contents ..............................................................................................................................iv

Thesis Introduction..............................................................................................................................1

SECTION ONE: LITERATURE REVIEW ...............................................................................................3

Literature Review Introduction ..........................................................................................................4

Part One: Background of Surfing ......................................................................................................4

Surfers’ personalities ..........................................................................................................................4

History and Participation ..................................................................................................................5

- Origin of surfing ..............................................................................................................................5
- Surfing competitions .......................................................................................................................6
- Surfing in New Zealand ..................................................................................................................6

Functional Demands of Surfing ........................................................................................................8

- Length of surf sessions ....................................................................................................................9
- Activity of a surf session ..................................................................................................................9
- Time motion analysis .....................................................................................................................10
- Physiological demands of surfing ................................................................................................12

Benefits of Surfing: From a Māori Health Model Perspective .........................................................13

- Taha tinana: Body...........................................................................................................................13
- Taha hinengaro: Psychological ......................................................................................................14
- Taha wairua: Spiritual ....................................................................................................................16
- Taha whānau: Family ......................................................................................................................16

Part Two: Sports Injury Prevention Research and Definitions .......................................................18

Injury Prevention Research Models ................................................................................................18

Injury Surveillance Studies .................................................................................................................19

Injury Definitions ...............................................................................................................................20

- Recurrent injuries ..........................................................................................................................22

Injury Reporting ...............................................................................................................................22
Injury causation ................................................................. 22
Injury severity ................................................................. 24
Injury classifications ......................................................... 24
Injury risk, incidence rate and injury prevalence .................. 25
Aetiology and Mechanism of Injury .................................. 25

Part Three: Previous Studies on Surfing Injuries .................. 26
Overview of Methods Employed in Previous Research .......... 26
Emergency department studies ....................................... 27
Other studies using medical notes .................................... 27
Retrospective studies ...................................................... 28
Summary of studies from emergency departments and using medical notes ........................................ 30
Summary of retrospective survey studies ......................... 30
Challenges Related to Definitions of Surfing in Previous Studies ........................................... 32
Challenges in Injury Reporting and Implications for Inter-studies Comparisons .................. 33
Injury causation ................................................................. 33
Injury severity ................................................................. 34
Frequency of injuries ...................................................... 35
Incident rates of injury .................................................... 36
Injury prevalence ............................................................ 36
Injury risk ....................................................................... 37
Nature of Injuries ............................................................ 38
Type of injury ................................................................. 38
Location of injury ........................................................... 40
Mechanism of injury ....................................................... 46

Conclusion ........................................................................ 48

References ........................................................................ 50

SECTION TWO: MANUSCRIPT ........................................... 61

Abstract ........................................................................... 62
Objectives ......................................................................... 62
Methods ............................................................................ 62
Results .............................................................................. 62
Conclusion ......................................................................... 62
Introduction .............................................................................................................................63

Methods ..................................................................................................................................64
  Design .....................................................................................................................................64
  Eligibility ................................................................................................................................64
  Questionnaire design ............................................................................................................64
  Data collection procedures ...................................................................................................65
  Injury Definitions ..................................................................................................................65
  Data Analysis ........................................................................................................................66

Results .......................................................................................................................................67
  Demographics ........................................................................................................................67
  Total gradual-onset major injuries .........................................................................................67
  Incident rate and prevalence ..................................................................................................72
  Injury risk factors ................................................................................................................72
    Surfing ability-levels and competitive versus recreational surfers .......................................72
    Board types: long-boards versus short-boards ...................................................................74
    Other risks ........................................................................................................................74

Discussion ................................................................................................................................76
  Common injuries and mechanism .........................................................................................76
  Gradual-onset versus chronic injuries .................................................................................77
  The influence of surfing-related variables on surfing injury risk ........................................78
    Years of surfing and surfers age .........................................................................................78
    Hours of surfing ................................................................................................................78
    Influence of lack of out of water training contributing to injuries ......................................79
  Injury risk across surfing ability-levels and competitive status ..........................................79
  Injury risk for long-boarders versus short-boarders ............................................................80
  Shoulder injuries ................................................................................................................81
    Shoulder impingement syndrome ......................................................................................81
  Study limitations ..................................................................................................................81
    Recall bias ........................................................................................................................81
    Respondent bias ................................................................................................................82
  Future study recommendations ..........................................................................................82
  Conclusion ............................................................................................................................83
  Key Findings ........................................................................................................................84
Thesis Introduction

The popularity of surfing is growing worldwide as well as in New Zealand (NZ). There are numerous health benefits associated with surfing participation including physical, mental, social and spiritual. Benefits of surfing need to be considered against ‘harms’ particularly injury. In NZ, including Māori, consequences of surfing injuries include detrimental effects on health as well as economic costs to the community through healthcare compensation and time off work. Compared with other sports, relatively little is known about preventing injuries associated with surfing. Therefore, there is a compelling need for injury prevention research to address surfing in order to identify the incidence and severity of injuries, the aetiology and mechanism of injury, introduce preventative measures and assess the effectiveness of these for surfers (van Mechelen, 1997).

In NZ, The Accident Compensation Corporation (ACC), a unique compulsory personal no-fault injury cover for New Zealanders, spent almost $5 million (NZD) in 2014 on surfing injury claims - a figure that had increased 35% since 2010. Lowdon, Pateman, and Pitman (1983) predicted over 30 years ago that more shoulder injuries may prevail in the future due to boards becoming shorter with less floatation that would require more paddling stress as well as improvement in wetsuit designs that might increase the hours of exposure to surfing. Despite these early warnings, surfing injury prevention research, especially on gradual-onset injuries is still scarce. One reason for this lack of research may be the recreational and the unorganized nature of surfing, which is undertaken by individuals rather than teams.

The aims of this thesis are to investigate the nature of the most common gradual-onset surfing injuries in NZ. This is fundamental information to guide the development of surfing injury prevention protocols for surfers (Finch, 2006; van Mechelen, Hlobil, & Kemper, 1992). The study that made-up this thesis surveyed NZ surfers using an online questionnaire where the surfers retrospectively reported any gradual-onset surfing related injuries that they had experienced in the past 12 months. The location, type and mechanism of injury were investigated, along with risk factors for injury.

The thesis is structured in three sections as a Literature Review (Section One), Manuscript (Section Two), and Appendices (Section Three). The Literature Review outlines the background, growth and popularity of surfing; along with a discussion of the health
benefits associated with surfing including physical activity, as well as psychological, spiritual and social aspects of surfing. Even though this thesis is not undertaking a risk-benefit analysis of surfing, these health benefits of surfing are considered in the context of potential harms caused to surfers when they are unable to participate in surfing due to injury. Considering the magnitude and impact of harm may be the first step to develop a clearer understanding of the consequences of surfing injuries. Next, the literature review investigates sports injury prevention research models and recommendations for reporting sports injuries. Lastly, it reviews current surfing injury epidemiology studies that have investigated the extent, nature and mechanism of surfing injuries. The manuscript reported in Section Two is formatted for *British Journal of Sports Medicine* and reports the results of a retrospective survey of 1473 surfers’ gradual-onset surfing injuries in NZ over a 12-month period. The type of tissue injured, body parts injured, mechanism of injury and risk factors of surfing injuries are reported for this study and discussed in the context of other studies. The Discussion section include recommendations for future surfing injury studies to assist with the development of surfing injury prevention protocols. The Appendices (Section Three) includes ethics documentation, and a copy of the questionnaire used in this study.
SECTION ONE:
LITERATURE REVIEW
Literature Review Introduction

Recent research on surfing injury has explored the nature of injuries and proposed ways that they might be prevented. The first part of this literature review explores the background of surfing, with particular reference to surfing in NZ, and the need to prevent surfing injuries. The second part reviews sports injury prevention models for research and reviews methodological issues related to sports injury epidemiology including injury definitions. The third part critically examines research from previous surfing injury studies from which recommendations are drawn for future surfing injuries research towards developing injuries prevention initiatives.

Part One: Background of Surfing

Surfing is an activity performed in the ocean by surfers riding waves on surfboards, which are floatable vessels often constructed from polyurethane foam and fibreglass (Loveless & Minahan, 2010; A. Mendez-Villanueva & Bishop, 2005). The surfer first paddles to accelerate the board in an attempt to match the velocity of the wave while lying in the prone position on a surfboard. The surfer then ‘pops up’ to their feet to ride the face of the wave as it moves towards the shoreline (Loveless & Minahan, 2010; A. Mendez-Villanueva & Bishop, 2005). Surfing is often described as a recreational sport enjoyed by people from a range of socioeconomic backgrounds, ages, geographical locations, and genders (Frank, Zhou, Bezerra, & Crowley, 2009; A. Mendez-Villanueva & Bishop, 2005). The amount of time surfing varies widely between surfers. While some people may surf only occasionally, many surfers regard surfing as a fundamental part of their everyday life and a noticeable surf culture has evolved especially in coastal communities (Meir, Zhou, Rolfe, Gillear, & Coutts, 2012; Pearson, 1979, as cited in Moran & Webber, 2013). Farmer and College (1992) described surfing culture as having limited organisation and no rules, with particular behavioural norms and alternative views. Farmer and College (1992) noted that these behaviours and views tend to be influenced by peer pressure and “charismatic authority figures” from within the surfing culture rather than having a hierarchy of leadership.

Surfers’ personalities

Given the idea of the surfing culture, surfing is frequently considered a different type of activity to mainstream sports with surfers often having different motivations to participate compared to mainstream athletes (Farmer & College, 1992). “Surfing fits into all
categories. It’s an ART by the way you express yourself on a wave. It’s a SPORT because you compete with it, and it’s SPIRITUAL because it’s just you and Mother Nature” (Moriarity and Gallagher 2001 as cited in B. Taylor, 2007, p. 924). Diehm and Armatas (2004) claimed that surfers were inclined to have an active imagination, aesthetic sensitivity, give attention to inner feelings, have a preference for variety, intellectual curiosity and independence of judgement. Additionally, a quasi-experimental study in Australia between 41 surfers from a high-risk sport, and 44 golfers from a low-risk sport, showed that surfers have stronger personality characteristics for sensation seeking and may crave adventurous and risky activities (Diehm & Armatas, 2004). The study reported that the surfers’ intrinsic motivations were also higher than the golfers, which is suggestive of surfers seeking pleasure and satisfaction from the activity of surfing itself. These higher risk-taking personalities, observed in surfers, may increase injury risk for surfers compared to athletes from low risk sports such as golf. Therefore, as the popularity of surfing grows so does the need to understand and prevent surfing injuries, particularly those that may have a different impact on the athlete compared to low risk sports injuries.

**History and Participation**

The worldwide surfing population has been steadily growing with estimates of 18 million surfers in 2002 by Nathanson, Haynes, and Galanis (2002), and which has now reached an estimated 23 million in 2016 (Statistic Brain, 2016).

**Origin of surfing.** Surfing was an ancient sport in Polynesia and Micronesia and is considered by most scholars to have originated in Hawai’i over 1000 years ago with reports of Hawai’ians riding primitive surfboards (Meir et al., 2012; A. Mendez-Villanueva & Bishop, 2005; Nathanson, Bird, Dao, & Tam-Sing, 2007; Nathanson et al., 2002; K. S. Taylor, Zoltan, Achar, & Achar, 2006). Often referred to as the ‘sport of kings’ (O’Rourke, 2006, April; Thompson, 2016), surfing was popular amongst Hawai’ian royalty, such as King Kamehamehaa in the 18th century (A. Mendez-Villanueva & Bishop, 2005; Te Kanawa, 2017, January 3), as well as with the commoners (Nathanson et al., 2002). In the late 1800s participation in Hawai’i started to decline due to discouragement by Christian missionaries (D. Taylor, Bennett, Carter, Garewal, & Finch, 2004), possibly due to religious beliefs associated with surfing (B. Taylor, 2007), and had almost completely vanished by the end of the 19th century (Nathanson et al., 2002). Duke Kahanamoku, a Hawai’ian Olympic swimming champion, is often called the ‘father of
modern surfing’ due to his influence in the revival of surfing (Gilio, 2016). He created interest in surfing around the world when he demonstrated surfing at beaches in Australia, California, Europe and NZ (A. Mendez-Villanueva & Bishop, 2005; Nathanson et al., 2002; O'Rourke, 2006, April; Swarbrick, 2006). However, George Freeth, Duke’s friend and mentor, is considered by some commentators to have been more influential in the resurgence of surfing than Duke, since it was Freeth who was the first lifeguard and also introduced surfing to California in 1907 (Gilio, 2016; O'Rourke, 2006, April). But unlike Duke, who was full-blooded Hawai’ian, Freeth was hapu halo (mixed blood). Freeth’s hapu halo status has been suggested by some as a reason why Duke, instead of Freeth, was regarded in Hawai’ian culture as the patriarch of modern surfing (Gilio, 2016).

**Surfing competitions.** The first competitions of the modern era of surfing were held in Hawaii, Australia and California during the 1960s (Nathanson et al., 2007), and in 1964 the first world surfing championship was held in Australia (A. Mendez-Villanueva & Bishop, 2005). Participation in surfing is believed to have increased rapidly since the 1960s (Furness et al., 2014) with a surge in the 1990s as lifestyle surfing apparel became popular and surfing commercialism exploded (Nathanson et al., 2002). During the last 20 years there has also been significant developments in surfboard design and accessories (Dimmick, Gillett, Sheehan, Sutton, & Anderson, 2014).

Recently it has been announced that surfing will be introduced as a new sport in the 2020 Tokyo Olympics (Olympics, 2017). Over the last 20 years the Olympics have already introduced an assortment of action sports in an attempt to connect with younger people (Thorpe & Wheaton, 2016). Stefani (2016) suggests this paradigm shift towards these predominantly recreational sports may become the future for the Olympics. There has been controversy around this with concerns amongst action-sport participants, including surfers, that their alternative lifestyle activities do not match the rules, hierarchies and nationalistic views of the Olympics (Stefani, 2016; Thorpe & Wheaton, 2016).

**Surfing in New Zealand.** The popularity of surfing in NZ is not surprising since NZ has an estimated coastline of 15,000 – 18,000 km that is exposed to waves from the Southern Ocean, Pacific Ocean, and the Tasman Sea (Gordon, Beaumont, MacDiarmid, Robertson, & Ahyong, 2010; Gorman, Bryan, & Laing, 2003). This expansive coastline spans over 10 degrees of latitude allowing easy access for most New Zealanders to
numerous surf breaks (Pickrill & Mitchell, 2010). From anywhere in NZ it is never more than 130 km to the coast (Walrond, 2005) and the summer water temperatures are also favourable for surfing ranging from 13 degrees in the South to 21 degrees in the North; but slightly less favourable during winter ranging from 9.5 to 16 degrees (Garner, 1969).

**New Zealand surfing population.** Currently, the NZ population of surfers has been estimated to be approximately 155,000 (>15 years of age) (Haughey, Gray, & Heffield, 2015; MacPherson, 2014). This estimate was calculated by multiplying the 2014 NZ census population >15 years of age (3.59M) (MacPherson, 2014), by the surfing participation rate of 4.3%. This participation rate was reported in the 2013/14 Sports and Active Recreation NZ survey of people >15 years of age who had participated in surfing during the preceding 12 months (Haughey et al., 2015). To give some context to the size of the surfing population in NZ, a comparison with other popular sports is insightful. Rugby, the perceived national sport of NZ (Bird et al., 1998), has a lower participation rate of 3.6% in NZ compared to 4.3% for surfing (Haughey et al., 2015). A water safety survey in 2003 that focused on NZ high school children <16 years of age (n=2202) reported 65% of respondents had surfed in the previous year, with 25% of the children considering themselves as regular surfers (Moran, 2003, as cited in Moran & Webber, 2013). This illustrates that there is also a substantial proportion of surfers <16 years of age in NZ, which would increase estimates of the total NZ surfing population.

**The history of indigenous surfing in New Zealand.** Jhan Gavala, a Māori surfer, psychologist and academic, is currently researching ancient Māori surfing by collecting kōrero (an oral Māori tradition of stories and narratives) (Moorfield, 2017a) and other documentation from around NZ (Te Kanawa, 2017, January 3). Drawing on collected kōrero, Gavala believes that Māori were surfing over 700 years ago on the west coast of the North Island in Taranaki (Te Kanawa, 2017, January 3). He also suggests that around that era, there were Māori living in Aotearoa (NZ) who had their own surfing rangatira (Māori leaders/chiefs), in particular Te Rangituataka from Ngāti Maniapoto. Written accounts of observations in journals written by Pākehā (New Zealanders of European decent) have reports of Te Rangituataka, along with his brothers, surfing in the late 1800s (Te Kanawa, 2017, January 3). These first European settlers report witnessing Māori surfing on boards called waka kōpapa (Swarbrick, 2006). Gavala reports that these waka kōpapa (short canoes made from hollowed-out logs) were mostly between 2 – 4 feet but
some were up to 6 foot 2 inches (Te Kanawa, 2017, January 3). Other types of boards that Māori reportedly used to surf were waka hourua (double-hulled canoes) and Ngāpuhi (the largest Māori iwi based in Northland (Taonui, 2015)) surfers used boards called moki (Te Kanawa, 2017, January 3). There are also kōrero of Māori using hui (gourd plant) to surf by putting them under their underarms and surfing face first down the wave, similar to body surfing (Te Kanawa, 2017, January 3). Ancient Māori female surfers were reported by Gavala to be “incredible” surfers and according to stories the men had to “prove they were worthy” to these females through competitions that were watched by the whole community (Te Kanawa, 2017, January 3). Similar to the decline in surfing that occurred during the late 19th century in Hawaii, surfing in NZ also declined during the same era due to the influence and subsequent deterrence to avoid surfing by the first Christian missionaries (Swarbrick, 2006). A revival in surfing occurred during the NZ visit of Duke Kahanamoku in 1915 with his surfing demonstrations in Auckland, Wellington and Christchurch being widely attributed to initiating a revival of the sport in NZ (Swarbrick, 2006).

**Māori surfing today.** Surfing still appears to be popular with Māori who have a strong cultural connection with the ocean (Swarbrick, 2006). The Māori community have organised surfing events including the Māori Surfing Championships. This was recently held in Taranaki where the event started in the early 1990s to encourage Māori surfing (Te Kanawa, 2017, January 3). The governing body of surfing in NZ, Surfing New Zealand (SNZ)/ Retiri Ngaru o Aotearoa, have also selected Māori surfing teams who have competed internationally. These teams include the Auahi Kore Aotearoa Surfing Team who placed second in the Oceania Cup in Tahiti in 2008 (Team SNZ, 2008, 2009). Currently, some of NZ’s top surfers identify as being Māori including Ricardo Christie who competed with the world top 32 surfers in the World Championship Tour during 2015 (Simpson, 2015). Additionally, Māori competitor Daniel Keraopa won The Ultimate Waterman 2015, an international multi discipline event that included surfing and was hosted in NZ (The Ultimate Waterman, 2015).

**Functional Demands of Surfing**

Even though the popularity of surfing is growing as a sport, as evidenced by inclusion of surfing in the 2020 Tokyo Olympic Games, sports performance research for surfing is still limited (Loveless & Minahan, 2010; A. Mendez-Villanueva & Bishop, 2005). This may
be partly due to a predominant view of surfing as a recreational activity, and a lack of recognition by surfers that they are exercise training (A. Mendez-Villanueva & Bishop, 2005). Surfing requires physical fitness that requires biomechanical skills and physiological adaptations to both the upper and lower body (A. Mendez-Villanueva & Bishop, 2005). A small number of studies have undertaken objective measures of the demands of surfing including duration of surf sessions (Meir et al., 2012), time-motion analysis of the different activities performed within a surf session (Farley, Harris, & Kilding, 2012b; Meir, Lowdon, & Davie, 1991; J. Mendez-Villanueva, Bishop, & Hamer, 2003) and physiological demands on the surfer (Farley et al., 2012b).

**Length of surf sessions.** Two hours has been suggested to be a typical length of time for a surf session, although this may vary from surf session to session (Meir et al., 2012). Meir et al. (2012) reported the majority (79%) of surf sessions were between 1 – 2.5 hours, and 20% of surfers reported some surf sessions exceeding 3 hours (Meir et al., 2012). When surf conditions are favourable, the duration of a session may be as long as 4 – 5 hours (A. Mendez-Villanueva & Bishop, 2005), and a second surf session within the same day is common (Meir et al., 2012). Felder, Burke, Lowdon, Cameron-Smith, and Collier (1998) suggest that competitive surfers may spend between 1 – 5 hours in the water training per day, although competition heats are only 15 – 40 minutes in duration. Contests are often held over a 10-day holding period with organisers running the competition when the conditions are best (Nathanson et al., 2007). Apart from these competitions, it appears that each individual surfer’s level, or whether they are competitive or recreational, does not determine time spent in the water (A. Mendez-Villanueva & Bishop, 2005). Season length may have been influenced by the improvement of wetsuit designs allowing surfers to stay in the water longer in colder temperatures (A. Mendez-Villanueva & Bishop, 2005), thus, surfing is now a year-round sport for many, not confined to just the warmer summer months.

**Activity of a surf session.** The three main parts of the activity of surfing that are repeated numerous times during a surf session are ‘paddling’, ‘pop up’, and ‘wave-riding’ (Loveless & Minahan, 2010). The paddling stage is when the surfer paddles out into the waves to the take-off spot while lying in the prone position on a surfboard (Loveless & Minahan, 2010; A. Mendez-Villanueva & Bishop, 2005). The prone paddling position involves hyperextension of the neck and lower back (A. Mendez-Villanueva & Bishop,
2005) while repeatedly paddling with the arms in a front crawl style. As a suitable wave comes closer the surfer must generate sufficient speed with some powerful paddle strokes to project forward onto the face of the wave (A. Mendez-Villanueva & Bishop, 2005). During the pop up stage the surfer pushes themself up quickly from a lying to standing position on the board (Loveless & Minahan, 2010). Wave-riding is achieved once the surfer is standing on their feet riding across the unbroken wall or face of a wave while the wave moves towards the shoreline (Loveless & Minahan, 2010; A. Mendez-Villanueva & Bishop, 2005).

**Time motion analysis.** Studies have used time-motion analysis to investigate the amount of time during a surf session that surfers spend paddling, riding the wave, being stationary while waiting for waves, and other miscellaneous activities (Farley et al., 2012b; Meir et al., 1991; J. Mendez-Villanueva et al., 2003). Differences between studies for the time spent on each activity during a surf session may be due to specific external demands that may differ between recreational and competitive surfing or environmental conditions. External demands during competitive surfing include tactical decisions, heat opponents and wave selection in competitions. Influential environmental factors include swell size, type of wave including length and frequency, type of ocean floor, ocean currents and consistency of swell (A. Mendez-Villanueva & Bishop, 2005).

Time-motion analysis has demonstrated that the majority of time surfing, approximately 50%, is spent with the surfer lying prone while paddling (A. Mendez-Villanueva & Bishop, 2005). Meir et al. (1991) videoed six recreational surfers for one hour, from when they entered the water, concluding that recreational surfers spent 44% of their time paddling. J. Mendez-Villanueva et al. (2003) video recorded 42 international competitive surfers during 25-minute elimination heats and reported 51% of the time was spent paddling. Farley et al. (2012b) have more recently used a global positioning system (GPS) while videoing 12 national level surfers in competition heats to analyse time-motion patterns. They recorded surfers paddling 54% of the time, plus an additional 4% of the time spent as high intensity paddling for the wave as a separate category (Farley et al., 2012b).

Riding the wave is defined by Meir et al. (1991) as the time from when the surfer’s feet land on their surfboard until the surfer finishes riding the wave as their feet detach from
the board. It appears to comprise only a small proportion of total surfing time. In a study of recreational surfers riding the wave made up just 5% of surfing time (Meir et al., 1991). Comparatively, in another study of competitive surfers (J. Mendez-Villanueva et al., 2003) wave riding time was slightly less at 3.8%. A more recent NZ-based study of surfers during surfing competitions showed that 8% of surfing time was spent riding the wave (Farley et al., 2012b), over double the proportion reported by J. Mendez-Villanueva et al. (2003). The authors acknowledged that environmental elements may have had major influences on these variations of time-motion analyses between studies (Farley et al., 2012b). For example, the length of the wave varies immensely between locations such as ‘point breaks’\(^1\) which often have much longer rideable sections of the wave compared to ‘beach breaks’\(^2\).

Surfers are reported to be stationary while waiting for waves approximately 40% of the time in the water (A. Mendez-Villanueva & Bishop, 2005). Meir et al. (1991) describe this stationary time as when the surfer is either lying or sitting on their boards, or using one arm to paddle slowly to keep their position in the take-off zone. Recreational surfers were reported to be stationary about 35% of the time. Comparatively, surfers during competitions have been reported to be stationary for 42% by J. Mendez-Villanueva et al. (2003) study and only 28% of the time by Farley et al. (2012b).

\(^1\) A common description of the term ‘point break’, as described by Wikipedia, is where the wave wraps around a point of land and breaks over rocks, reef or sandy ocean bottoms (Wikipedia, 2016b).

\(^2\) A common description of the term ‘beach breaks’, as described by Wikipedia, are waves that break over sandy ocean bottoms and may vary in length and consistency (Wikipedia, 2016b).
Miscellaneous activities performed by surfers include wading in the water, ‘duck-diving’\(^3\) under the waves, and retrieving the surfboard after falling off. These activities accounted for 16% of the time for recreational surfers (Meir et al., 1991) but only 2.5% of the time for competitive surfers (J. Mendez-Villanueva et al., 2003). This may be much less for competitive surfers due to time limitations during a surfing heat, more experience at getting in and out of the water and more control over their surfboard.

**Physiological demands of surfing.** Surfing is an intermittent activity with varying intensities and durations that include: high intensity bouts of aerobic and anaerobic physiological demands mixed with low intensity aerobic exercise; numerous recovery periods and a variety of demands on the musculoskeletal system due to the use of many different body parts (Farley et al., 2012b; A. Mendez-Villanueva & Bishop, 2005). Paddling requires aerobic and anaerobic fitness plus intermittent endurance, and strength and power in the upper body. The lower body is used for wave riding which requires dynamic balance, rapid force development, flexibility, fast reaction time and coordination (A. Mendez-Villanueva & Bishop, 2005). Competitive surfers have been reported to have specific physical attributes such as mesomorph somatotypes, as well as often being shorter and with lower body mass compared to other aquatic athletes of similar competitive levels (A. Mendez-Villanueva & Bishop, 2005).

---

\(^3\) ‘Duck-diving’ involves the surfer pushing the surfboard under oncoming waves while paddling to the take off point (Nathanson et al., 2007).
Benefits of Surfing: From a Māori Health Model Perspective

The participation in sporting activities, such as surfing, has numerous health benefits (van Mechelen et al., 1992; Verhagen & van Mechelen, 2010b) which include reducing the risk of “diseases of the sedentary” such as cancer and heart disease (Quarrie et al., 2001). When aspects of surfing related to health are reviewed using the lens of a Māori health model, there may be specific health benefits pertinent to Māori (Ministry of Health, 2015).

Endorsed by the NZ Ministry of Health, the current Māori health model that translates as ‘te whare tapa whā’ was constructed and proposed by Sir Mason Durie, a Professor of Māori studies widely recognised for his contributions to Māori health (Ministry of Health, 2015; Wikipedia, 2016a). Te whare tapa whā takes a holistic approach to health that expands beyond the physical and mental health perspectives of modern Western health systems (Ministry of Health, 2015). The four cornerstones of te whare tapa whā are: taha tinana, bodily component/physical health; taha hinengaro, the psychological component/mental health; taha wairua, the spiritual component; and taha whānau, the family component (Durie, 1985; Ministry of Health, 2015). Based on this model of well-being, if one component is impaired or missing then an individual, or collective, may become unwell (Ministry of Health, 2015).

**Taha tinana: Body.** The bodily component of the Māori health model is familiar to Western health systems where the physical body is usually the major focus (Durie, 1985). Within te whare tapa whā, physical health is required for optimal physical development and growth (Ministry of Health, 2015). Surfing requires high levels of physical fitness with a variety of physical demands on both the upper and lower body as well as the cardiovascular system (A. Mendez-Villanueva & Bishop, 2005). These physical demands result in physiological improvements to: aerobic and anaerobic fitness (Farley, Harris, & Kilding, 2012a; A. Mendez-Villanueva & Bishop, 2005); intermittent muscular and cardiovascular endurance (Farley et al., 2012a; A. Mendez-Villanueva & Bishop, 2005); strength and power (Farley et al., 2012a; A. Mendez-Villanueva & Bishop, 2005); reactive and proactive balance; flexibility and coordination (A. Mendez-Villanueva & Bishop, 2005); neuromuscular functions and postural control (Frank et al., 2009). Surfers’ aerobic fitness levels, particularly during maximal oxygen consumption arm exercise tests, have been reported in studies as consistently higher than untrained individuals and are comparable to other upper body endurance athletes (A. Mendez-Villanueva & Bishop, 2005). In a small study of 6 male recreational surfers (Meir et al.,
surf paddling was shown to be an effective aerobic fitness workout. Study participants’ heart rate while paddling was 80% of their maximum heart rate obtained during a maximal oxygen consumption test with a bench ergometer (Meir et al., 2012). Loveless and Minahan (2010) compared 8 competitive surfers with 8 recreational surfers to investigate peak oxygen uptake and efficiency of paddling. They reported no difference between recreational and competitive surfers for peak oxygen uptake and paddling efficiency but reported significantly higher blood lactate concentration in the recreational surfers during submaximal paddling in an incremental paddling test. From these data, the authors suggest lactate thresholds may improve relative to the surfer’s ability (Loveless & Minahan, 2010). Improvements in lactate thresholds may arise from physiological adaptations in response to the greater demands of competitive surfing training or may reflect a predisposition to greater fitness levels in the competitive compared to recreational surfers. Another study of 12 nationally-ranked surfers showed a significant correlation between national ranking during the competitive surfing season and individual anaerobic power ($p = 0.05$) (Farley et al., 2012a). A comparative study investigated the long-term neuromuscular functions between long-term recreational surfers aged 55 – 65 years who had surfed for the past 20 years, and still surfed, on a weekly basis; and matched healthy active, similarly-aged non-surfers (Frank et al., 2009). This study highlighted that older surfers had better postural control when standing upright and greater control over steady muscle contractions (Frank et al., 2009). The health benefits of long-term recreational surfing are suggested by Frank et al. (2009) to improve and maintain neuromuscular function and therefore may improve quality of life in older life.

**Taha hinengaro: Psychological.** Thoughts, feelings, emotions and the ability to communicate have traditionally played an important role in Māori health and the Western health system has also come to a similar realisation as to the importance of this psychological component (Durie, 1985; Ministry of Health, 2015). There are numerous cognitive demands involved in surfing which require tactile decision-making for wave selection; navigating around other surfers and adapting to numerous environmental conditions (A. Mendez-Villanueva & Bishop, 2005). Māori academic, Jordan Waiti, believes surfing enhances the development of awareness, patience, focus, concentration and analytical skills (J. Waiti - Ngāti Pikiao, Te Rārawa, personal communication, April 20, 2015). Some surfers also claim they can clear their mind instantly when surfing, like the clarity that yogis achieve through meditation (Morton, 2013). Additionally, physical
inactivity in general has been suggested to have a casual relationship with the incidence of depression (McWha, Smith, & Clarke, 2000). Due to a possible lack of organised sports in rural communities compared to urban areas, coupled with the easy access to the coast in NZ, surfing may be an important part of rural surfers’ mental health in NZ.

**Nature reducing stress levels.** The stress-reducing benefits of physical activity and being immersed in nature while surfing may also have positive effects on the psychological well-being of surfers (Archer, Fredriksson, Schütz, & Kostrzewa, 2011; McEwen & Sapolsky, 1995). Reducing chronic stress has become an important health issue since stress is now recognised to be a contributing factor to many diseases including Type 2 diabetes (Kyrou & Tsigos, 2009), cardiovascular disease, cancer, and mental health disorders (Sapolsky, 2004). Kaplan’s (1995) “Attention Restorative Theory” hypothesises that natural environments reduce stress levels through “soft fascination”, which is described by Kaplan as “involuntary attention” that is utilised when surrounded by nature. “Soft fascination” is believed to be responsible for the restoration of “direct (voluntary) attention” that is believed to be required, but depleted in urban environments (Kaplan & Berman, 2010). Aspinall, Mavros, Coyne, and Roe (2013) reported a reduction of direct attention in a study in which participants wore a mobile electroencephalograph while walking from an urban retail street into a natural green environment (a park). Reductions in frustration and arousal also occurred as participants transitioned into the more natural environment. The aquatic environment presents unique challenges for investigating these responses in surfers. Recently, during a research trial in Mexico, a mobile electroencephalograph was worn while surfing and this development holds promise for undertaking similar studies with surfers (Strickland, 2014). Japanese studies also reported a significant reduction in stress levels in Japanese urbanites when they were exposed to forests and natural environments. This was evident with decreases in salivary cortisol levels (Park, Tsunetsugu, Kasetani, Kagawa, & Miyazaki, 2010), decreased salivary amylase circadian rhythms (Yamaguchi, Deguchi, & Miyazaki, 2006), reduced urinary noradrenalin levels (Li et al., 2011), reduced blood pressure (Li et al., 2011; Park et al., 2010), reduced pulse rate along with increases in parasympathetic activity (Park et al., 2010) and reduced sympathetic activity (Li et al., 2011; Park et al., 2010). Therefore, the benefits of being completely surrounded by nature while surfing may help reduce stress levels, improve mental health as well as prevent physical stress-related diseases.
**Taha wairua: Spiritual.** Often in modern health settings there is an absence of recognition for the spiritual component of health (Ministry of Health, 2015). In contrast, te whare tapa whā believe invisible energies are related to health, and damage to an individual’s spirit may be considered as a contributing factor to physical illnesses (Ministry of Health, 2015). Many Māori, including Jess Santorik, the previous Māori female surfing Champion, believe the spiritual component of surfing for Māori include connections with Tangaroa/Hinemoana, the Māori god/goddess of the sea/ocean (J. Santorik - Ngāti toa and Ngāti tama, personal communication, June 21, 2015; J. Waiti - Ngāti Pikiao, Te Rārawa, personal communication, April 20, 2015). Surfers with different religious beliefs may also have connections to their gods through their experiences in the ocean. This is evident in religious scriptures such as the Bible in Genesis 1:2 which states “…and the Spirit of God was hovering over the waters” (The Zondervan Corporation (Producer), 2005). In addition, another sub-group of surfers sometimes described as “soul surfers” describe the spiritual experience while surfing as a belief that nature is transformative, powerful, sacred and healing (B. Taylor, 2007).

The sea holds a magic for those of us who know her. A magic so simple, pure and powerful it works as an unseen force in our souls. We’re drawn to her. The spirit of the sea moves in us as we move within her, undulating folds in pursuit of our peace. As surfers, we inherently know this to be so. The sea brings comfort, solace, release and escape. The sea brings healing. The spirit of the sea, for some of us, is the very essence of life. (Glendon 2005: 70 as cited in B. Taylor, 2007, p. 946)

**Taha whānau: Family.** This concept of whānau (family) health refers to belonging, caring and sharing as part of a larger social system (Ministry of Health, 2015). The whānau component, is often embraced when extended families go surfing together and gather for surfing events (J. Waiti - Ngāti Pikiao, Te Rārawa, personal communication, April 20, 2015). There are local iwi (tribe) surfing games such as the Waikato-Tainui Games that encourage participation of tamariki (children), gathering of whānau and promotion of health and wellbeing of their iwi (Te Whakakitenga o Waikato, 2017). The term whānau has been defined as “extended family, family group, a familiar term of address to a number of people … In the modern context … friends who may not have any kinship ties to other members” (Moorfield, 2017b, p. 1). Therefore, the feeling of belonging to a community within a surfing sub-culture or scene may also be regarded as whanau by some, regardless of blood ties. This may be important to Māori and non-
Māori alike especially in coastal rural communities in NZ where surfing is popular and there are often less organised social activities in comparison to urban areas.

Due to the growing popularity of surfing, the unique characteristics of the surfing culture and surfer’s personalities, and the relevance of surfing to the NZ context, surfing may be a major part of life for many New Zealanders including Māori. Therefore, it is imperative to prevent surfing injuries to allow surfers to continue to participate in surfing and reap the health benefits of the physical, psychological, spiritual and social aspects of surfing.

Importantly, following the recommendations for sports injury prevention, research is a vital component of developing relevant and effective surfing injury prevention protocols.
Part Two: Sports Injury Prevention Research and Definitions

The risk of sports injury is a recognised threat to positive health outcomes associated with participating in sport and involves both direct and indirect costs to athletes as well as society (Verhagen & van Mechelen, 2010a). Developing and applying injury prevention frameworks based on epidemiological research, to mitigate sports injuries, has become an important goal of researchers, coaches, athletes and international sporting bodies (Junge et al., 2008; van Mechelen et al., 1992; Verhagen & van Mechelen, 2010a). Part Two of this literature review examines the recommendations for sports injury prevention research frameworks, injury definitions and reporting of injuries for injury surveillance studies, and aetiology and mechanism of injury.

Injury Prevention Research Models

Epidemiology studies provide essential information that guides the development of injury prevention, treatment and rehabilitation protocols (Brooks & Fuller, 2006). In the early 1990s a four-step model (Figure 1) for sport injury prevention research was developed by van Mechelen et al. (1992) with an emphasis on injury risk and aetiology as crucial parts of prevention research (Verhagen & van Mechelen, 2010a). van Mechelen et al. (1992) suggested that firstly the extent of the issue of the sports injury should be determined and secondly, the mechanism of injury should be established. Next, prevention protocols should be introduced to reduce the risk and severity of potential injuries, and lastly these measures should be tested by repeating the first step (van Mechelen et al., 1992). Not considered in this 4-step model were behaviour changes and how these prevention protocols are adapted and accepted by sporting bodies, athletes and coaches (Verhagen & van Mechelen, 2010a). Therefore, Finch (2006) proposed a new framework with six steps called Translating Research into Injury Prevention Practice, or TRIPP (Figure 1). This framework incorporates additional steps that focus on translating proven prevention measures in research settings to the real-world sports environment (Finch, 2006). Notably, the first step is still the same as the model by van Mechelen et al. (1992), which suggests epidemiology studies are required to establish the extent of the injury problem through database analysis, surveillance, literature studies or other forms of data collection (Verhagen & van Mechelen, 2010b). Many surfing injury studies have explored step 1 and partially step 2 from the perspective of these models for traumatic injuries (Bentley, Macky, & Edwards, 2006; Dimmick et al., 2014; Furness et al., 2015; Hay, Barton, &
Sulkin, 2009; Klick, Jones, & Adler, 2016; Meir et al., 2012; Moran & Webber, 2013; Nathanson et al., 2007; Nathanson et al., 2002; Roger & Lloyd, 2006; D. Taylor et al., 2004; Woodacre, Waydia, & Wienand-Barnett, 2014). Only three previous studies have investigated step 1 for gradual-onset injuries (Furness et al., 2014; Nathanson et al., 2002; D. Taylor et al., 2004) with only one of these studies incorporating step 2 (Furness et al., 2014).

<table>
<thead>
<tr>
<th>Model steps</th>
<th>TRIPP</th>
<th>van Mechelen et al four-steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Injury surveillance</td>
<td>Establish extent of the problem</td>
</tr>
<tr>
<td>2</td>
<td>Establish aetiology and mechanism of injury</td>
<td>Establish aetiology and mechanism of injury</td>
</tr>
<tr>
<td>3</td>
<td>Develop preventative measures</td>
<td>Introduce preventive measures</td>
</tr>
<tr>
<td>4</td>
<td>“Ideal conditions”/scientific evaluation</td>
<td>Assess their effectiveness by repeating step 1</td>
</tr>
<tr>
<td>5</td>
<td>Describe intervention context to inform implementation strategies</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Evaluate effectiveness of preventive measures in implementation context</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1: Comparison of injury prevention research models. Adapted from Finch (2006).

Injury Surveillance Studies

Several authors have identified methodological issues between sports injury epidemiology studies that have caused conflicting conclusions and difficulties with inter-study comparisons including differences in injury definitions, and methods of data collection and analysis (Brooks & Fuller, 2006; Fuller et al., 2006; King, Gabbett, Gissane, & Hodgson, 2009). Therefore, many authors highlight the importance of consensus of sports injury definitions for these epidemiology studies so there can be effective comparisons between studies with conclusions that lead to development of prevention protocols (Brooks & Fuller, 2006; Fuller, Molloy, et al., 2007; Junge et al., 2008; Meeuwisse & Love, 1997; van Mechelen et al., 1992; Verhagen & van Mechelen, 2010b). Essential parts in the methodological design and reporting of studies which are elaborated on in the next section include defining ‘injury’ and ‘recurrent injury’; reporting methods such as the seriousness and duration of injury; and describing calculation methods of injury incidence and prevalence (Brooks & Fuller, 2006; van Mechelen, 1997).
Injury Definitions

Definitions of ‘sports injury’ range from any type of tissue damage resulting from physical activity to very specific criteria that reference insurance claims, accessing of medical services, or attenuated or adapted sports or work participation (van Mechelen et al., 1992). The proposed definition for sports injuries by the Council of Europe in 1989 was:

Any injury as a result of participation in sport with one or more of the following consequences: (a) a reduction in the amount or level of sports activity; (b) a need for (medical) advice or treatment; and (c) adverse social or economic effects. (van Mechelen et al., 1992, p. 85)

van Mechelen et al. (1992) discuss how requirements of an insurance claim being submitted or treatment from a medical centre to qualify as a sports injury may limit the reporting of injuries and exclude injuries with a gradual-onset or injuries that have not received medical attention. van Mechelen et al. (1992) therefore suggested a definition for sports injury as, “all types of damage that occur in relation to a sporting activity” (p. 84).

Since 2005 there have been several attempts to develop consensus based sports injury definitions which have mostly been sports-specific including football (soccer) (Fuller et al., 2006) rugby union (Fuller, Molloy, et al., 2007), rugby league (King et al., 2009) and for the Olympics (Junge et al., 2008). There appears to be a merging of a universal injury definition towards those proposed for the globally popular sport of football (Verhagen & van Mechelen, 2010b). This consensus definition for football injury was published in 2006 as:

Any physical complaint sustained by a player that results from a football match or football training, irrespective of the need for medical attention or time loss from football activities. An injury that results in a player receiving medical attention is referred to as a “medical attention” injury, and an injury that results in a player being unable to take full part in future football training or match play as a “time loss” injury. (Fuller et al., 2006, p. 193)

Similar definitions with some slight variations have been suggested for rugby union and rugby league (Fuller, Molloy, et al., 2007; King et al., 2009). The definition for rugby union was almost identical with only one additional part about how the injury was caused, “Any physical complaint, which was caused by a transfer of energy that exceeded the
body’s ability to maintain its structural/or functional integrity…” (Fuller, Molloy, et al., 2007, p. 329). For rugby league, the definition changed a few words of the football definition from “Any physical complaint…” to “Any pain or disability…”. Additionally, more clarification was added to time loss and medical attention aspect of the definition, “…need for match or training time loss or for first aid or medical attention…” (King et al., 2009, p. 13).

The International Olympic Committee also adopted a variation of these definitions which excluded injuries that did not receive medical attention rather than having an additional category for ‘medical attention injury’ (Junge et al., 2008). This definition was “any musculoskeletal complaint newly incurred due to competition and/or training during the tournament that received medical attention regardless of the consequences with respect to absence from competition or training” (Junge et al., 2008, p. 414).

More recently, Verhagen and van Mechelen (2010b) proposed the following ‘unified’ definition for sports injury intended to be applied across all sports injury research:

Any physical complaint (caused by a transfer of energy that exceeds the body’s ability to maintain structural and/or functional integrity) sustained by an athlete during competition or training directly related to the sport or exercise activity investigated, irrespective of the need for medical attention or time-loss from athletic activity. (Verhagen & van Mechelen, 2010b, p. 44)

This may be appropriate for surfing application because the definition would capture any physical complaints sustained during surfing competition or training, or injuries directly related to the activity of surfing in a recreational context.

Further to these definitions it is suggested that injuries unrelated to the sport, either competition or training, should be excluded from injury surveillance studies (Fuller et al., 2006; Verhagen & van Mechelen, 2010b). This may be important for surfing injury studies since anecdotally many surfers also participate in other activities such as skateboarding and snow-sports. In addition, Fuller et al. (2006) recommends when an athlete has numerous injuries from one incident it should be recorded as, “one injury with multiple diagnoses” (p. 193), but this will only be appropriate with an assessment from a medical practitioner or other healthcare practitioner to obtain a diagnosis. Furthermore, the International Olympic Committee state, in agreement with the rugby and football consensus statements, that recurrent injuries should not be included in surveillance and
only new injuries should be reported (Junge et al., 2008). Although there may be difficulties in identifying what are recurrent injuries compared to new injuries.

**Recurrent injuries.** Recurrent injuries present a particular problem in quantifying the extent of sports injuries because clinical judgement is required to determine whether the injury is the same as a previous injury (Brooks & Fuller, 2006). Verhagen and van Mechelen (2010b) define a recurrent injury as “an injury of the same type and at the same site as an index injury that occurs after an athlete’s return to full participation in training and/or competition from the index injury” (p. 45). Fuller, Bahr, Dick, and Meeuwisse (2007) have proposed dividing recurrent injuries further to ‘exacerbations’, injuries that occur when an index injury is not completely recovered; and ‘re-injuries’, which occur when an index injury is completely recovered. Being ‘fully recovered’ would also require clinical judgement by a healthcare practitioner.

**Injury Reporting**

**Injury causation.** Verhagen and van Mechelen (2010b) suggest injuries should also be defined by the cause or onset of injury as either, “traumatic (i.e. caused by a single, specific, and identifiable event) or gradual-onset (i.e. caused by repeated micro-trauma without evidence of a single, identifiable event)” (p. 50-51). Stovitz and Johnson (2006) note that previous literature on sporting injuries have often inappropriately referred to these categories of causation as ‘acute’ and ‘overuse’. For example, van Mechelen (1997) defined acute injuries as, “injuries that are the result of a single macro-trauma” and overuse as, “injuries that are the result of repetitive micro-trauma” (p. 166).

Two main difficulties arise with the use of both of these terms to identify the causation of injuries. Firstly, traumatic injuries have sometimes been referred to interchangeably as ‘acute injuries’, which can be problematic as acute injuries appear to have a dual meaning. As well as being used for causation, acute injuries are commonly used as an antithesis of chronic injuries, both of which relate to the time-frame (duration) of injury. A medical dictionary illustrates this dual definition of acute as, “having a sudden onset, sharp rise, and a short course … compare chronic… lasting a short time” (Medline Plus, 2017a). ‘Chronic’ is then defined as, “marked by long duration, by frequent recurrence over a long time… not acute” (Medline Plus, 2017b). Importantly, The International Association of the Study of Pain (1994) distinguishes acute and chronic pain in relation to duration. Chronic pain has been defined as “pain which persists past the normal time of healing”
(International Association of the Study of Pain, 1994, p. 4) and this may be <1 month or >6 months (International Association of the Study of Pain, 1994; Jordan, Holden, Mason, & Foster, 2010). Three months is suggested to be the most appropriate time point to distinguish between acute and chronic pain for non-malignant pain. In spite of this, it is noted that some researchers use 6 months as the dividing time point (International Association of the Study of Pain, 1994). The 3-month boundary appears to be the common use for musculoskeletal injury research (Casanova-Mendez et al., 2014; Jordan et al., 2010; Maiers et al., 2014; Rubinstein, van Middelkoop, Assendelft, de Boer, & van Tulder, 2011). In a Cochrane review on the effects of spinal manipulative therapy for chronic low-back pain, chronic pain was defined as pain persisting for 12 weeks or longer (Rubinstein et al., 2011). Another Cochrane review on adherence to exercise interventions for patients with chronic musculoskeletal pain also used an inclusion criteria of participants having pain for 3 months or longer (Jordan et al., 2010). In two chronic neck pain studies, pain persisting for a minimum of 3 months was also considered chronic (Casanova-Mendez et al., 2014; Maiers et al., 2014). One surfing injury study also defined injuries that persisted for >3 months as chronic (Furness et al., 2014).

The second difficulty is that ‘overuse’ is another term that is often used interchangeably with gradual-onset injuries. Debate around this use of the term centres around the lack of evidence of the association between overuse injuries and the activity levels of athletes (Gregory, 2002; Verhagen & van Mechelen, 2010b). The term ‘overuse’ is often used in the absence of the identifiable traumatic event. The term is categorised medically as ‘cumulative trauma disorder’, which is defined as a, “harmful and painful condition caused by overuse or overexertion of some part of the musculoskeletal system, often resulting from work-related physical activity. Overuse is characterised by inflammation, pain or dysfunction of the involved joint, bones, ligaments, and nerves” (Gregory, 2002, p. 82). This definition of overuse states that cumulative trauma disorder is caused by overuse but fails to actually define overuse. It may imply that a work load has been excessive and injury occurs when structural limitations have been exceeded by use (Gregory, 2002). Traumatic injuries have also been excluded from the overuse category, but it has been argued that certain types of traumatic injuries also fit the category of overuse (Gregory, 2002). One example might be tibial fractures resulting from tackles in football which are more common in athletes who play or train the most, and who may be more strongly predisposed to trauma due to existing micro-injury (Gregory, 2002). Furthermore, if overuse is being used then the term ‘underuse’ is suggested for athletes who are injured.
due to lack of training or inactivity (Stovitz & Johnson, 2006; Verhagen & van Mechelen, 2010b). Stovitz and Johnson (2006) query whether gradual-onset injuries commonly occur from lack of use or adaptation of a body part to a subsequent unfamiliar movement, rather than overuse of the body part. Applying the term overuse may also have negative effects on the promotion of the health benefits of physical exercise by over-emphasising the risk of injuries coming about from doing too much exercise (Stovitz & Johnson, 2006). Gregory (2002) therefore suggests avoiding using the term overuse for sports injuries until there is more evidence that overuse is the predominant casual factor for these injuries.

**Injury severity.** In addition to causation, sports injuries may be further defined by the severity of injury. Indices of severity can include seriousness or duration according to tissue damage, time loss, medical attention, catastrophic or fatal injuries (Brooks & Fuller, 2006; Fuller et al., 2006; van Mechelen, 1997; Verhagen & van Mechelen, 2010b). Multiple authors report time-loss as lost time from participation in the sport, which includes both training and competition (Brooks & Fuller, 2006; Fuller et al., 2006; van Mechelen, 1997; Verhagen & van Mechelen, 2010b). Match loss is suggested to be a more severe level of injury by Verhagen and van Mechelen (2010b) who define the time-loss concept as, “The number of days elapsed from the date of injury to the date the athlete’s return to full participation in training and availability for competition” (p. 48). Fuller et al. (2006) define time-loss for football as, “An injury that results in the player being unable to take a full part in future football training or match play” (p. 194). In addition to sporting time-loss, work and study time-loss are suggested to be included when defining severity of injury (van Mechelen, 1997). Medical attention injury can range from first aid to hospitalisation and involves any assessment by a qualified healthcare practitioner (Fuller et al., 2006; Verhagen & van Mechelen, 2010b). Medical diagnosis, treatment and surgery may also be included in definitions of injury severity (Brooks & Fuller, 2006; van Mechelen, 1997). ‘Non-fatal catastrophic injuries’, for example, were defined as, “A brain or spinal cord injury that results in permanent (>12 months) severe functional disability (Verhagen & van Mechelen, 2010b, p. 48).

**Injury classifications.** The Orchard Sports Injury Classification System (OSICS) was developed in 1992 as a classification system for injury incidence studies (Rae & Orchard, 2007). Since then many revisions have been made with the most recent OSICS-10 having 18 classifications for anatomical site of injury including: head, neck, shoulder, upper arm, elbow, forearm, wrist and hand, chest, trunk and abdomen, thoracic spine,
lumbar spine, pelvis and buttock, hip and groin, thigh, knee, lower leg, ankle, and foot (Rae & Orchard, 2007). According to Rae and Orchard (2007) these anatomical sites may be combined into more basic classifications, which may be beneficial to obtain basic injury information in surfing studies. The structure injured is also classified by OSICS into six main groups with sub-groups: Bone (fracture, other bone injuries); Joint (non-bone) and Ligament (dislocation, subluxation, sprain, ligament injury, lesion of meniscus, cartilage, disc); Muscle and Tendon (muscle rupture, tear, strain, cramps, tendon injury, rupture, tendinopathy, bursitis, haematoma, contusion, bruise); Skin (abrasion, laceration); Central and Peripheral Nervous Systems (concussion, structural brain injury, spinal cord compression, transection, nerve injury); Other (dental injury, visceral injury, other injuries) (Fuller et al., 2006; Verhagen & van Mechelen, 2010b). Although OSICS is important in injury research, it is not appropriate for self-reported surveys because OSICS requires a trained healthcare practitioner to diagnose and code injuries accordingly.

**Injury risk, incidence rate and injury prevalence.** Injury risk can be a generic term for incidence of injury (Hopkins, Marshall, Quarrie, & Hume, 2007), which when not clearly defined may lead to confusion between reporting in studies. In addition to generic use, injury risk can be a specific statistic reported as a decimal fraction or percentage which is the proportion of a specific group of athletes who are injured (Hopkins et al., 2007). Incident rate (IR) (sometimes referred to as ‘incidence’) is the number of injuries over a time period divided by a measure of the total athlete exposure to the sport during the same time period (Hopkins et al., 2007). Reporting of IR can be calculated from several different bases, such as injuries per 1000 player-hours; per 1000 athlete-exposures; per 1000 matches (Brooks & Fuller, 2006). Injury prevalence (IP) applies to the proportion of people with an injury in a specific population over a period of time (van Mechelen, 1997). Importantly, estimating IR requires accurate data about participation exposure time which is not available in retrospective studies without being subject to recall bias. In retrospective studies, researchers can ask respondents to report hours of participation, but given the bias involved this should be interpreted as crude estimates. Ideally, prospective study designs would be more appropriate for accurate calculations of IR.

**Aetiology and Mechanism of Injury**

The second step of injury prevention protocols refers to the aetiological factors and mechanism of injury. van Mechelen (1997) defines aetiology factors of injury as factors
leading to changes in prevalence, incidence and duration/seriousness of injuries, whereas mechanism of injury is defined as the actual conditions that impose sufficient stress on the body during the sporting activity to cause tissue damage. Exploring the aetiology and mechanisms of injury is predicated by step 1 of the TRIPP framework (to establish the extent of the problem), therefore it is important to obtain better step 1 information for surfing injuries before continuing to this next stage of research.

**Part Three: Previous Studies on Surfing Injuries**

Overall, the surfing injury literature is limited to a few epidemiology studies addressing the first two stages of the TRIPP framework for sports injury prevention research (determining extent and cause). The final part of this review examines the common surfing injuries reported in these previous studies. Definitions of the term ‘surfing’ have been inconsistent between studies, which has caused difficulties with inter-study comparisons with some studies including other surf-related activities such as body surfing and boogie boarding while other studies have excluded these. Additionally, studies have used a variety of methodologies and variations in injury reporting which have also created complications for drawing over-arching conclusions, although some common patterns have emerged.

Most of these studies have reported ‘traumatic’ injuries as ‘acute’ injuries (Furness et al., 2015; Nathanson et al., 2007; Nathanson et al., 2002; D. Taylor et al., 2004; Woodacre et al., 2014) while the three studies on ‘gradual-onset’ surfing injuries have used the problematic term ‘chronic’ to define injury causation (Furness et al., 2015; Nathanson et al., 2002; D. Taylor et al., 2004). In this section, the methodology of previous studies including the definitions used for surfing and injury reporting are described. Results from these studies, including who gets injured the most; injury incidence and prevalence; and injury risk are reported. Finally, discussion will focus on the nature of injuries, with the most common types, body parts injured, and mechanisms identified.

**Overview of Methods Employed in Previous Research**

Research methods have included analysis of injuries from medical reports either from emergency departments (ED) (Dimmick et al., 2014; Hay et al., 2009; Klick et al., 2016; Roger & Lloyd, 2006; D. Taylor et al., 2004); medical staff at professional and amateur surfing competitions (Nathanson et al., 2007); lifeguards at NZ beaches (Moran & Webber, 2013); and data from ACC injury claims (Bentley et al., 2006) (Table 1). Other
studies have used retrospective surveys either through face-to-face administration with surfers at beaches (D. Taylor et al., 2004), or on the internet (Furness et al., 2014; Furness et al., 2015; Meir et al., 2012; Nathanson et al., 2002; Woodacre et al., 2014) (Table 1).

**Emergency department studies.** Of the 5 identified ED studies, each varies in size, duration and geographic location (Dimmick et al., 2014; Hay et al., 2009; Klick et al., 2016; Roger & Lloyd, 2006; D. Taylor et al., 2004) (Table 1). In Australia, D. Taylor et al. (2004) used a broad dataset of surfing injuries presented to 26 EDs in Victoria over 6 years. On a lesser scale, Roger and Lloyd (2006) collected data on surfing injuries presented at one ED in Byron Bay, Australia, as three sets of cross-sectional data each collected over three separate years. Hay et al. (2009) also reported injuries from only one ED, which was the main ED in Cornwall, United Kingdom (UK). Dimmick et al. (2014) investigated only a small number of head and face injuries from the radiology department at the Sydney ED, Australia. Klick et al. (2016), reported the largest amount of surfing injuries by collecting data in the United States of America (USA) from a national injury ED database (Table 1).

**Other studies using medical notes.** Nathanson et al. (2007) reported surfing injuries from competitive surfers that were recorded by on-site medical professionals during heats or practice at 32 surfing competitions: 22 professional and 10 amateur (Table1). Participants were 95% short-boarders with boards generally 7 feet or smaller, and the remainder of participants were riding long-boards (Nathanson et al., 2007), which is expected given that short-boards are the most common in surfing competitions.

NZ data from a 2006 study of ACC records was reported by Bentley et al. (2006) (Table 1). ACC only covers physical injuries that are caused by an accident; or gradual conditions that are work-related (Accident Compensation Corporation, 2016a). An ACC registered health provider must fill out the ACC claim form for an injury (Accident Compensation Corporation, 2016b). Then ACC may provide financial support for medical treatment and injury rehabilitation costs; compensation for loss of earnings due to time off work; home help and transportation costs related to injuries (Accident Compensation Corporation, 2016c). Therefore, only traumatic (or acute) surfing injuries that required medical attention were analysed in this study (Bentley et al., 2006). This epidemiology study on adventure sports in NZ reported 18,697 claims over a 1-year period from 28 adventure sports and activities that cost $15 million (NZD) (Bentley et al., 2006). Surfing
was one of the four adventure sports that, when combined, the four sports total injury claims represented the majority of all adventure sport injury claims. Surfing accounted for 12% of these adventure sports injury claims with a median cost per injury case of $103.70 (NZD) (Bentley et al., 2006).

Another NZ study by Moran and Webber (2013) reported surfing injuries recorded by NZ Lifeguards during summer months from 2007 – 2012 (Table 1). These surfing injuries accounted for 16% of total injuries recorded by lifeguards during this period (Moran & Webber, 2013). There were a few limitations with this study including the lifeguards were not necessarily professional medical personnel which may question the validity of injury reporting; not all data included the cause or nature of injury which made it difficult to confirm that the injury was caused by surfboard riding; and the definition of surfing was not specific and was inclusive of many other surf-based activities (Moran & Webber, 2013).

Retrospective studies. Other epidemiology studies have been conducted using retrospective surveys involving data collected at surf beaches (D. Taylor et al., 2004) or via the internet (Furness et al., 2014; Furness et al., 2015; Meir et al., 2012; Nathanson et al., 2002; Woodacre et al., 2014) (Table 2). Nathanson et al. (2002) undertook a worldwide observational survey that was online from May 1998 until August 1999 and completed by surfers from 48 countries. D. Taylor et al. (2004) collected data during the summer of 2003 for a cross-sectional survey using an interviewer-administration approach with surfers in beach carparks as they exited the water at eight popular surf beaches in Victoria, Australia. Meir et al. (2012) collected surfing injury data from surfers residing in Australia through a survey available online for 4 weeks. Woodacre et al. (2014) distributed an online survey to over 50 UK surfing clubs in 2012, which included recreational, life-guarding, professional and university clubs. Furness et al. (2014) collected data from surfers in Australia using a cross-sectional descriptive survey that was online for 5 months and resulted in two separate studies, one on chronic surfing injuries (Furness et al., 2014) and the other on acute injuries (Furness et al., 2015). In the beach survey by D. Taylor et al. (2004) and the recent Australian survey (Furness et al., 2014; Furness et al., 2015) surfers were required to have been active surfers for at least 12 months, which excluded the ‘rookie surfers’ defined by Roger and Lloyd (2006) as having less than 1 year surfing experience (Table 1).
Table 1: Surfing Injury Studies.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Location of Emergency Departments</th>
<th>Study Time</th>
<th>Injury Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Klick et al. (2016)</td>
<td>USA</td>
<td>2002 – 2013</td>
<td>2071</td>
</tr>
<tr>
<td>Roger and Lloyd (2006)</td>
<td>Byron Bay, Australia</td>
<td>June – July</td>
<td>Total =303</td>
</tr>
<tr>
<td></td>
<td>Three sets of cross-sectional data each</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>collected over three separate years.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dimmick et al. (2014)</td>
<td>Radiology; Sydney, Australia</td>
<td>2008 – 2012</td>
<td>29</td>
</tr>
</tbody>
</table>

Other medical notes studies; Location

| Nathanson et al. (2007)       | Competitions; Hawaii, USA, Australia,  |
|                              | Tahiti, Argentina.                    | 1999 – 2005 | 116            |
| Bentley et al. (2006)         | ACC data; NZ                          | 2004 – 2005 | 2238           |

Survey type; Location; Respondent numbers; Number of injured surfers

| Nathanson et al. (2002)       | Internet; Worldwide 48 countries (USA 76%, NZ 2%); 1348 respondents | May 1998 – August 1999 | 1237 acute; 477 chronic |
| Furness et al. (2014);       | Internet (with beaches); Australia; | 5 months;            | 739 acute              |
| Furness et al. (2015)        | 1348 respondents                     | 2013                  | 883 chronic            |
| D. Taylor et al. (2004)      | 8 surf beaches; Victoria, Australia; 646 respondents;               | Summer; 2003;         | 168 acute; 146 chronic |
|                              | 145 acute, 136 chronic              |                      |                |
| Meir et al. (2012)           | Internet; Australia; 685 respondents; 272 injured surfers          | 4 weeks;             | 389             |
| Woodacre et al. (2014)       | Internet; UK from 50 surfing clubs; 130 respondents; 122 injured surfers | 6 months;            | 135 acute        |
|                              | 2012                                  |                      |                |

Abbreviations: USA = United States of America; UK = United Kingdom; ACC = Accident Corporation & Compensation; NZ = New Zealand.
Summary of studies from emergency departments and using medical notes. A strength of the study by Klick et al. (2016) is the large number of injuries recorded which were collected from a national injury database possibly capturing a large proportion of surfing injuries presented to EDs in the USA. Klick et al. (2016) acknowledged a limitation of this study outlining that data was collected from a pre-existing database of medical records that was not especially designed for surfing injuries. A similar study by D. Taylor et al. (2004) reported surfing injuries from 26 EDs that represented approximately 80% of all ED injuries in the state of Victoria, Australia (D. Taylor et al., 2004). In contrast, Hay et al. (2009) highlighted the possibility that injuries in more remote locations were not covered in the UK ED study. Even though the Cornwall ED was the main ED in the county in which the study was undertaken, there were other satellite and smaller clinics where surfers may have reported their injuries (Hay et al., 2009). In comparison, Roger and Lloyd (2006) contended that even though their study only sampled data from one ED, it was likely to capture the majority of major surfing injuries in the area as the next nearest ED was over 20 km away. Another advantage of the study by Roger and Lloyd (2006) was that data were collected longitudinally in three different years, so changes in the number of surfing injuries could be compared across time. Dimmick et al. (2014) only investigated ED head and face injuries which may have allowed more in-depth understanding and exploration of these types of injuries. Limitations of this study by Dimmick et al. (2014) were the small sample size and only reporting injuries from the radiology department, which may have limited the types and severity of injuries captured.

A general limitation of all studies that have utilised medical notes (from EDs, other medical professionals and lifeguards) is that they are likely to under-report the true incidence rate of surfing injuries and only explore the nature of these severe or traumatic injuries. This is due to studies not including injuries presented to primary or other healthcare practitioners; injuries that do not require medical treatment but may have required time off work, study or surfing; gradual-onset injuries; and minor injuries (Klick et al., 2016; Moran & Webber, 2013; Nathanson et al., 2007).

Summary of retrospective survey studies. Recall bias reduces the validity of any retrospective survey with the potential for memory decay of participants (Jenkins, Earle-Richardson, Slingerland, & May, 2002). Gabbe, Finch, Bennell, and Wajswelner (2003) reported from a small study on 70 Australian rules football players that there was a 100%
recall ability of whether an injury was sustained in the previous 12 months; but they also noted only 61% of participants recalled the details of these injuries accurately during this time period. They suggest that in retrospective surveys, as more detail about the injury is requested, the capacity to accurately recall injury detail declines (Gabbe et al., 2003). Another study reported that participant’s injury recall accuracy significantly decreases when recalling injuries that occurred more than 2-months prior (Jenkins et al., 2002). The accuracy of injury recall was reported to continue to decrease significantly from injuries in the past 12 months to injuries within the last 10 years (Jenkins et al., 2002). This illustrates a limitation from the study by Nathanson et al. (2002) as participants recalled injuries over the last 5 years. This limitation of reduced recall accuracy, although to a lesser degree, also occurred in all four studies that used retrospective reports of injuries occurring in the previous 12 months (Furness et al., 2014; Furness et al., 2015; Meir et al., 2012; D. Taylor et al., 2004).

The internet-based data collection from surfers with a history of injury and those without, may have had respondent bias towards injured surfers being more inclined to participate due to the relevance to their current situation compared to uninjured surfers (Furness et al., 2014). Furness et al. (2014) tried to reduce the impact of this limitation by encouraging all surfers through survey promotions to participate, regardless of whether or not they were injured. In contrast, D. Taylor et al. (2004) collected data from surfers in beach carparks that may have reduced this respondent bias towards injured surfers by approaching “well surfers” who were currently actively involved in surfing. However, this may have caused a selection bias towards “well surfers” and any surfer currently not surfing due to serious or fatal injuries would automatically be excluded (D. Taylor et al., 2004). One other limitation that D. Taylor et al. (2004) noted was that chronic injuries were not easy to report accurately since often symptoms of these injuries were non-specific.

A general limitation that occurs in all self-reported surveys is the lack of medical expertise in the responses that increases the likelihood of inaccurate data (Nathanson et al., 2002). In internet surveys Meir et al. (2012) proposes that there is an assumption that participants have the literacy ability to comprehend questions. Also, the internet allows anonymity that may lead to spurious responses; therefore, the honesty, and ability, of participants to answer correctly is relied upon by researchers (Meir et al., 2012; Nathanson et al., 2002). The interviewer-administration process of surveys at beaches may have helped to reduce
these limitations. An additional limitation acknowledged by Furness et al. (2015) was that recurrent injuries were not able to be identified, as only one injury per body part was able to be reported because of the questionnaire structure and details about previous injuries were not investigated. There are pros and cons of different types of retrospective surveys and on balance the online data collection compared with beachside surveys may introduce less bias.

Prospective studies are considered to more accurately report injury rates than retrospective data collection due to better reliability, completeness and elimination of recall bias (Jenkins et al., 2002; D. Taylor et al., 2004; van Mechelen, 1997). These prospective studies would be beneficial for future surfing injury research, although these require considerable resources and participant commitment. Therefore, there remains a need for retrospective data in order to help with design and conduct of future prospective studies, especially in NZ where there is not yet any larger scale retrospective data.

Challenges Related to Definitions of Surfing in Previous Studies
Surfing or surfboard riding has been defined in multiple ways with some studies refining their inclusion criteria specifically to injuries that have occurred while surfboard riding (Dimmick et al., 2014; Klick et al., 2016; Nathanson et al., 2007; Roger & Lloyd, 2006). In surfing competitions, this was considered either short or longboarding (Nathanson et al., 2007). Klick et al. (2016) described surfing as a “surfer paddling into a naturally generated wave, on an open body of water, and riding the wave in a standing position.” (p. 1491). There was a specific code for surfing injuries within the USA ED database and Klick et al. (2016) excluded 40% of injuries coded as surfing when the notes were reviewed and did not meet the outlined surfing criteria. Dimmick et al. (2014) included injuries that occurred while surfboard riding and the database was searched for these terms: surfing, surfer and surfboard. Injuries were then excluded if they were caused by water-based activities other than surfboard riding, such as bodyboarding, kite surfing, body surfing and paddle boarding (Dimmick et al., 2014). D. Taylor et al. (2004) searched patients’ notes for the keywords: surf, surfing, surfboard and board. A limitation of this study is that it was not confirmed whether boogie boarding, body surfing or other surf based and board activities were excluded (D. Taylor et al., 2004). Some studies have deliberately included body boarding (Hay et al., 2009; Moran & Webber, 2013), as well as body surfing, stand-up paddle boarding, knee boarding or kite boarding (Moran &
Webber, 2013), while other studies have excluded windsurfing and skim boarding (Hay et al., 2009), body surfing (Nathanson et al., 2002; D. Taylor et al., 2004), and boogie boarding (D. Taylor et al., 2004). Overall, the range of criteria used in previous studies to determine whether or not injuries are from surfing makes it difficult to characterise them or to accurately determine injury risk.

**Challenges in Injury Reporting and Implications for Inter-Study Comparisons**

**Injury causation.** Causation of the injuries were not defined as ‘traumatic’ or ‘gradual-onset’ in any of these previous surf injury studies (Bentley et al., 2006; Dimmick et al., 2014; Furness et al., 2014; Furness et al., 2015; Hay et al., 2009; Klick et al., 2016; Meir et al., 2012; Moran & Webber, 2013; Nathanson et al., 2007; Nathanson et al., 2002; Roger & Lloyd, 2006; D. Taylor et al., 2004; Woodacre et al., 2014) instead many of the studies used the terms ‘acute’ or ‘chronic’. Most of the ED studies (Dimmick et al., 2014; Hay et al., 2009; Klick et al., 2016; Roger & Lloyd, 2006; D. Taylor et al., 2004), the lifeguard study (Moran & Webber, 2013) and ACC study (Bentley et al., 2006) did not define causation of injury. The Sydney ED study on head and face injuries noted 26 injuries as acute, and 3 as chronic, but did not define these terms (Dimmick et al., 2014). Only acute injuries were recorded in the UK survey but again there was no definition provided (Woodacre et al., 2014). Injuries reported by Meir et al. (2012) were those that had kept the surfer out of the water during recovery. Nathanson et al. (2007) included only acute injuries at surfing competitions, defined as “sustained with a sudden-onset”, and injuries were excluded from the study if they were considered chronic or pre-existing.

Three studies using retrospective surveys (one published in two separate reports) collected information on both acute and chronic injuries (Furness et al., 2014; Furness et al., 2015; Nathanson et al., 2002; D. Taylor et al., 2004). The definitions of ‘acute’ and ‘chronic’ injuries in these surfing studies were referring mostly to the causation of injury, rather than the duration of injury as defined by the International Association of the Study of Pain (1994) and the use of these terms in surfing studies were not the same as used in other musculoskeletal research (Casanova-Mendez et al., 2014; Jordan et al., 2010; Rubinstein et al., 2011). Nathanson et al. (2002) described acute injuries as having a sudden impact or onset; and chronic injuries as either overuse or having gradual-onset. D. Taylor et al. (2004) did not define the term acute, and chronic injuries were described as chronic health problems that had generally resulted from surfing, including recurrent injuries and were
not considered acute. Furness et al. (2015) stated that a definition of acute injuries was
given at the start of questions in the survey but was not included in the published report.
With some investigation, it was found that this injury definition was,

...occur from a sudden impact or action while surfing. This normally involves a
sudden sharp pain that you can relate to a specific event while surfing. Please note
that a chronic injury is one that occurs over time and is different to acute injuries.
(J. Furness, personal communication, October 16, 2015)

Furness et al. (2014) described a chronic injury as gradual-onset injury that also must have
been present for >3 months. The definition provided to participants in the survey was,

Chronic injury is defined as a condition that occurs over a period of time with a
gradual-onset of symptoms. There may not be one specific event that caused the
pain or discomfort. For an injury to be classified as chronic it needs to have been
present for a period of 3 months or more. This may include injuries which flare up
and down depending on the amount of surfing performed. (J. Furness, personal
communication, October 16, 2015)

This definition by Furness et al. (2014) has excluded gradual-onset acute injuries that were
not present for 3 months; therefore, data on these injuries may have been classified as
other injuries or missed altogether.

**Injury severity.** Studies often reported injury severity using a variety of criteria.
Injuries were sometimes reported as ‘serious’, ‘significant’ or ‘major’ injuries depending
on the levels of medical attention that were required and/or time loss from activities. All
ED studies (Dimmick et al., 2014; Hay et al., 2009; Klick et al., 2016; Roger & Lloyd,
2006; D. Taylor et al., 2004), the lifeguard study (Moran & Webber, 2013), the ACC
study (Bentley et al., 2006) and the competition study (Nathanson et al., 2007) only
included injuries that received medical attention. Serious injuries in the USA and
Cornwall ED studies accounted for 3.5 – 10% of injuries, and occurred when patients
were either admitted (Hay et al., 2009; Klick et al., 2016), transferred to hospital (Klick et
al., 2016), or when they were fatal (0.1%) (Klick et al., 2016). Klick et al. (2016) reported
13.6% of patients who were admitted or transferred were 60 – 69 years of age and 9.4%
over 70 years. Roger and Lloyd (2006) defined serious injuries as either fractures,
dislocations or injuries that required follow up appointments other than standard removal
of sutures. Moran and Webber (2013) reported that further medical attention was required
by 20% of injuries as either a doctor referral or hospital transportation (4%). Nathanson et
al. (2007) described ‘significant’ injuries as those requiring one or more days off surfing, hospital transportation or on-site suturing.

Most survey studies reported injuries as either major or significant if they required medical attention from a healthcare professional and/or time loss of one day or more from work and/or surfing (Furness et al., 2014; Furness et al., 2015); and/or time off school (Nathanson et al., 2002; D. Taylor et al., 2004). Approximately two thirds of acute injuries were classed as significant by Nathanson et al. (2002) or major by Furness et al. (2014). Meir et al. (2012) reported surfers’ perceived consequences of their injuries, which were loss of income (7%), job limitations (8%), medical costs (18%), recreational activities limitations (35%), and early retirement (2%). Nathanson et al. (2002) also reported some categories individually including 26% of significant injuries requiring time loss from surfing, 66% for which medical care was sought and 8% requiring hospitalisation. At contrasting ends of this spectrum, Woodacre et al. (2014) reported that only 10% of injuries required medical attention whilst D. Taylor et al. (2004) reported 67% of injuries required time off surfing or work with a mean of 3 weeks off.

**Frequency of injuries**

Possibly due to the gender imbalance in the surfing scene (Franklin, 2016), in all the surfing studies reviewed, the majority of participants were males, with young males appearing to sustain the most surfing injuries. The average age of respondents in the survey studies were 28 – 35 years, with males accounting for 85 – 91% of the respondent surfers (Furness et al., 2014; Furness et al., 2015; Meir et al., 2012; Nathanson et al., 2002; D. Taylor et al., 2004; Woodacre et al., 2014). In studies set at EDs the average age for sustaining a surfing injury were very similar and ranged from 26 – 34 years and males represented 79 – 81% of those injured (Dimmick et al., 2014; Hay et al., 2009; Klick et al., 2016; Roger & Lloyd, 2006). A similar proportion (81%) of ACC claims for surfing injuries were lodged by males (Bentley et al., 2006), while surfing injuries recorded by NZ lifeguards were slightly less male-dominated at 68% (Moran & Webber, 2013). This pattern differed in surfing competitions with no significant difference in the incidence of injuries between male and female surfers (Nathanson et al., 2007). Surfers participating in competitions were also a similar age with the average age on the 2003 World Championship Tour being 27.5 years (A. Mendez-Villanueva & Bishop, 2005). Nathanson et al. (2007) reported a slightly lower mean age of 24 years for injured competitive surfers.
Only a few studies have identified the ethnicity of surfers and those studied appear to be predominantly European or ‘white’ (Klick et al., 2016; Moran & Webber, 2013). Klick et al. (2016) identified 76% of surfers were ‘white’. Moran and Webber (2013) identified 85% of surfers were European, and noted that this was a considerably higher proportion than the 62% European NZ population.

Surfing injuries have been suggested in some countries to be mostly sustained during the summer months. Hay et al. (2009) reported 77% of injuries in the UK were sustained during the summer months. In NZ, according to ACC data, the majority of surfing injuries occur during the January mid-summer holiday period (Bentley et al., 2006).

**Incident rates of injury.** Incident rates (IR) of major injuries reported in studies ranged from 1.7 – 6.6 injuries per 1000 hours surfed (Furness et al., 2015; Meir et al., 2012; Nathanson et al., 2007). Nathanson et al. (2007) reported 13 injuries per 1000 hours, of which 6.6 per 1000 hours were significant. This study also recorded IR as 2.9 injuries per 1000 heats in competitions (Nathanson et al., 2007). Furness et al. (2015) reported 1.79 acute major injuries per 1000 hours surfing. Whereas Meir et al (2012) reported the IR for severe injuries that required time off surfing as 3.5 injuries per 1000 hours surfed. Woodacre et al. (2014) instead of reporting IR, reported 91% of surfers had sustained at least one injury while surfing and 48% reported at least three injuries.

**Injury prevalence.** With the exception of the study by Furness et al. (2015) and the ACC data study (Bentley et al., 2006) injury prevalence (IP) is not reported in studies. This is possibly because IP would be irrelevant in studies reporting from medical notes and ED data as all the study participants are already injured and not representative of the actual surfing population. The ACC study reported surfing as having the fourth highest injury prevalence in NZ adventure sports with an IP of 11.1 injuries (for those who sought medical attention) per 1000 participants in 1 year (Bentley et al., 2006). This was calculated using the athlete population based on surfing participation data from sports and activity leisure by SPARC (Bentley et al., 2006). Furness et al. (2015) reported an IP of 38% acute major injuries per surfer per year. This was determined by dividing the total number of injured surfers by the total number of participants in the survey (Furness et al., 2015). Furness et al. (2015) acknowledges that the volunteer basis of internet studies specifically about surfing injuries have the limitation, as discussed previously, of potentially not being representative of the surfing population at large, therefore reducing
the validity of IP estimates.

**Injury risk.** There were some variations in the risk of injury between studies. Furness et al. (2015) reported an increased risk of acute injury for competitive surfers ($p<0.001$), surfers who surfed more than 6.5 hours per week and surfers who could execute aerial manoeuvres ($p<0.001$). For acute injuries, competitive surfers’ IP of 42% was significantly higher than recreational surfers’ IP of 35% ($p<0.001$) (Furness et al., 2015). The IP for surfers who could perform aerial manoeuvres was 48% which was higher than that of competitive surfers (Furness et al., 2015). In contrast, Furness et al. (2014) reported significantly more chronic injuries for recreational surfers compared to competitive ($p=0.034$) and also increased chronic injury risk for those surfers who could not perform aerial manoeuvres ($p<0.05$). Also, Nathanson et al. (2007) reported no significant differences in injury rates between professional or amateur competitive surfers. In contrast Meir et al. (2012) reported that national level competitive surfers had an increased risk of injury than competitive surfers of local competitions ($p<0.001$).

Furness et al. (2015) reported competitive surfers surfed significantly more hours compared to recreational surfers ($p<0.001$) and as expected (due to greater exposure) those with acute injuries also surfed more hours ($p<0.001$). Meir et al. (2012) also reported surfing more hours increased the risk of acute injury ($p<0.001$). In contrast, Furness et al. (2014) reported no difference in risk of a chronic injury related to hours surfing.

The age of surfers and the amount of years surfing are related and can also influence risk of injury. Older surfers had an increased injury risk for chronic injuries with a mean age of 39 years for injured compared to 34 years for uninjured surfers ($p<0.001$) (Furness et al., 2014). Nathanson et al. (2002) reported surfers who had been surfing 20 years or more had significantly more shoulder strain chronic injuries ($p<0.05$). Roger and Lloyd (2006) reported in the case series that ‘rookie’ surfers were those who had been surfing for less than 1 year versus ‘experienced’ surfers who had surfed for more than 1 year. There was an increase in rookie injuries from the case series in 1996 to 2002, which also coincided with an increase in minor injuries. Roger and Lloyd (2006) suggested this was relative to the increase in activity of surfing schools in the area which had grown from one surfing school in 1996 to four surfing schools in 2002. During the same time-period there had been a reduction in experienced surfers’ injuries with a similar number of major (serious) injuries, so a proportional decrease in severity may have occurred. Also, Roger
and Lloyd (2006) suggested that modifications such as soft fins and rubber edges on learner surfboards may have influenced the decrease in major (serious) injuries to rookies.

**Nature of Injuries**

**Type of injury.** Injury types were reported in most studies as lacerations, bruises or contusions, sprains or strains, fractures, dislocations or concussions (Hay et al., 2009; Klick et al., 2016; Moran & Webber, 2013; Nathanson et al., 2007; Nathanson et al., 2002; D. Taylor et al., 2004) (Table 2). Woodacre et al. (2014) used more precision for the strains and sprains by dividing this category into muscle/tendon tears/ruptures, and joint/ligament sprains. Furness et al. (2014) used the tissue structure to report the injury type as skin, muscle/tendon, joint/ligament, or bone and nerve (Table 2). The most common type of injury reported from almost all studies were lacerations, comprising 31 – 59% of all injuries (Hay et al., 2009; Klick et al., 2016; Meir et al., 2012; Moran & Webber, 2013; Nathanson et al., 2002; D. Taylor et al., 2004; Woodacre et al., 2014).

Although skin injuries made up only 17% of acute injuries in the study by Furness et al. (2015), which was remarkably less than the proportion of lacerations reported in other studies (Table 2). This difference may reflect board design changes, for example more flexible and softer fins (Roger & Lloyd, 2006) since the majority of lacerations were caused by surfers being struck by their own board (Nathanson et al., 2002). The proportion of injuries caused by being hit by surfboards was less for competitive surfers with approximately only half the lacerations caused by being hit by their own board (Nathanson et al., 2007). The lower proportion of own surfboard-impact injuries may be due to competitive surfers having greater control of their boards from more surfing experience (Nathanson et al., 2007). Additionally, surfers with less than 12-months experience were excluded by Furness et al. (2015) and this may have resulted in a lesser rate of lacerations. Also, ED studies may have been more likely to capture laceration injuries that required sutures or dressings.

Nathanson et al. (2007) reported a different pattern for competitive surfers to acute injury studies for injury type with sprains and strains being the most prevalent injury, accounting for 39% of all injuries, while lacerations were second at 30% and contusions third equal with fractures and dislocations. Furness et al. (2015) also reported strains and sprains as the most common injury with 29% of acute injuries being joint/ligament and 31% muscular/tendon injuries (Table 2). This study allowed participants to select more than one structure injured so injuries to some structures may be disproportionately accounted for.
(Furness et al., 2015). The increased representation of strains and sprains in this recent acute injury study compared to previous acute injury studies may be explained by board design advancements of smaller boards that allow greater manoeuvrability and increased torsional movements while riding the wave (Furness et al., 2015).

In most other studies sprains and strains were usually the second or third most common injury ranging from 12 – 21% of total injuries (Hay et al., 2009; Klick et al., 2016; Nathanson et al., 2002; D. Taylor et al., 2004; Woodacre et al., 2014), and alternated with bruises and contusions that ranged from 12 – 24% (Hay et al., 2009; Klick et al., 2016; Moran & Webber, 2013; Nathanson et al., 2007; Nathanson et al., 2002; Woodacre et al., 2014). The fourth or fifth most frequent injury types reported were fractures ranging from 3 – 14% and dislocations 2 – 12% (Furness et al., 2014; Hay et al., 2009; Klick et al., 2016; Nathanson et al., 2002; D. Taylor et al., 2004; Woodacre et al., 2014). Concussions, although reported less, ranged from 3 – 7% (Furness et al., 2014; Klick et al., 2016; Nathanson et al., 2002; D. Taylor et al., 2004; Woodacre et al., 2014), and are potentially more serious injuries because of the risk of drowning when these injuries occur (Table 2).

**Type of chronic injuries.** Furness et al. (2014) reported substantially less chronic skin injuries (0.5%) than acute skin injuries (17.2%) that were reported in separate reports but recorded in the same survey (Furness et al., 2015). The traumatic nature of lacerations and bruises may account for this vast difference of skin injuries from acute injury studies. The most common types of chronic injuries in this survey were muscle/tendon tears/ruptures at 24% or joint/ligament sprains at 44% (Furness et al., 2014). The two other chronic injury studies have not reported injury types in a style that align with other studies (Nathanson et al., 2002; D. Taylor et al., 2004) therefore a comparison was difficult to make. Nathanson et al. (2002) reported musculoskeletal injuries as being the most frequent type of chronic injury, and in another study D. Taylor et al. (2004) reported musculoskeletal pain or stiffness accounted for 48% of the chronic injuries (Table 2).
Table 2: Types of injury.

<table>
<thead>
<tr>
<th>Lacerations</th>
<th>Bruises</th>
<th>Sprains/Strains</th>
<th>Fractures</th>
<th>Dislocations</th>
<th>Concussions</th>
</tr>
</thead>
<tbody>
<tr>
<td>31 – 59%</td>
<td>12 – 24%</td>
<td>12 – 21%</td>
<td>3 – 14%</td>
<td>2 – 12%</td>
<td>3 – 7%</td>
</tr>
<tr>
<td>(Hay et al., 2009; Klick et al., 2016; Meir et al., 2012; Moran &amp; Webber, 2013; Nathanson et al., 2002; Woodacre et al., 2014)</td>
<td>(Hay et al., 2009; Klick et al., 2016; Nathanson et al., 2002; D. Taylor et al., 2004; Woodacre et al., 2014)</td>
<td>(Hay et al., 2009; Klick et al., 2016; Nathanson et al., 2002; D. Taylor et al., 2004; Woodacre et al., 2014)</td>
<td>(Hay et al., 2009; Klick et al., 2016; D. Taylor et al., 2004)</td>
<td>(Klick et al., 2016; Nathanson et al., 2002; D. Taylor et al., 2004; Woodacre et al., 2014)</td>
<td></td>
</tr>
</tbody>
</table>

Other reporting for acute injuries (Furness et al., 2015)

| 19% skin | 31% muscle/tendon | 29% joint/ligament | 7% nerve |

Competition injuries (Nathanson et al., 2007)

| 2nd | 2nd | 39% | 2nd |

Chronic injuries (Furness et al., 2014)

| 0.5% skin | 24% muscle/tendon | 4% bone | 5% nerve |

|        | 44% joint/ligament |

**Location of injury.** Head, face and neck injuries together were the body parts that comprised the most injuries in the majority of studies. Three studies reported head and face together as the body part most commonly injured ranging from 24% – 41%, (Bentley et al., 2006; Hay et al., 2009; Woodacre et al., 2014). Two other studies combined head and neck injuries and reported these as the most common body part injured (32% – 37%) (Moran & Webber, 2013; Nathanson et al., 2002). Four other studies reported the head, face and neck injuries either separately or in varied combinations, and when the three body parts were added together they were also the most common body area injured accounting for 21% – 46% of acute injuries (Furness et al., 2015; Klick et al., 2016; Meir et al., 2012;
D. Taylor et al., 2004). Nathanson et al. (2002) reported lacerations were the most frequently cited head injuries at 34%. Dimmick et al. (2014) reported 58% of the head and face injuries were due to the surfers being hit in the head by their own surfboard. Klick et al. (2016) categorised closed head injuries, such as intracranial hematoma, as internal organ injuries. These internal organ injuries represented 4.7% of all cases analysed and accounted for 13.4% of all serious injuries (Klick et al., 2016). Hay et al. (2009) reported 32% of major injuries were skull and cervical spine fractures. Serious head, face and neck injuries are reported in EDs as the most commonly reported ranging from 45% – 50% of all injuries (Hay et al., 2009; Klick et al., 2016; D. Taylor et al., 2004). This evidence has led to many recommendations for the use of protective helmets for preventing lacerations and reducing the seriousness of head injuries (Dimmick et al., 2014; Moran & Webber, 2013; Nathanson et al., 2002; D. Taylor et al., 2004; Woodacre et al., 2014). In spite of this, there appears to be no studies investigating the effectiveness of this strategy for injury prevention and in 2004, D. Taylor et al. suggested that protective head gear was not worn by many surfers, and this still appears to be valid now. Surfers have expressed resistance to wearing helmets because they perceive only a low risk of serious injuries combined with negative effects on performance, discomfort and undesirable appearance (Woodacre et al., 2014). Interestingly, in the UK survey only 10% of injuries required medical attention (Woodacre et al., 2014), therefore only some of these injuries may have been presented to EDs. This illustrates that even though surfing injuries are common, serious injuries appear to be relatively rare. Combining these results with the Cornwall ED study, that reported 41% of injuries were to the head and face (Hay et al., 2009), it is likely that less than 4% of all surfing injuries in the UK are head and face injuries that are serious enough to present to EDs. Woodacre et al. (2014) therefore believes the decision to use protective head gear, although it may prevent these serious head injuries, may be left to the individual’s discretion.

Some very serious surfing injuries would not be prevented by wearing helmets, notably, spinal injuries of the neck, which often result from contact with the seafloor (Moran & Webber, 2013; Nathanson et al., 2002). Hitting the seafloor is suggested to be the cause of 75% of cervical spine injuries often causing the lower cervical spine to hyperextend and resulting in either fractures or spinal cord damage (K. S. Taylor et al., 2006). Nathanson et al. (2002) reported 3% of injuries caused by surfers hitting the ocean floor, resulted in serious neck injuries. This included 7 cases of fractured vertebrae and three permanent deficits. K. S. Taylor et al. (2006) suggested that older surfers, especially if they have pre-
existing spondylosis, are more likely to suffer from these types of injuries.

The second most frequently injured body parts in some studies were the lower extremities which accounted for 18 – 37% of injuries (Hay et al., 2009; Klick et al., 2016; Nathanson et al., 2002). When the studies further divided lower extremity injuries into more specific body parts, ankle and foot, and knee injuries were often the second or third most commonly injured body parts, ranging respectively from 13 – 23% (Furness et al., 2015; Meir et al., 2012; Moran & Webber, 2013; D. Taylor et al., 2004; Woodacre et al., 2014), and 11 – 16% (Furness et al., 2015; Meir et al., 2012; D. Taylor et al., 2004; Woodacre et al., 2014). Woodacre et al. (2014) reported the only 2 injuries that required surgery were both anterior cruciate ligament reconstructions (Woodacre et al., 2014).

The upper extremities were usually the third most common body part injured accounting for 12 – 17% of injuries (Hay et al., 2009; Klick et al., 2016; Nathanson et al., 2002). Shoulders, when reported as a separate category, were also reported to be commonly injured ranging from 5 – 16% (Bentley et al., 2006; Furness et al., 2015; Hay et al., 2009; Meir et al., 2012; D. Taylor et al., 2004; Woodacre et al., 2014). Shoulder dislocations were serious injuries also often reported in acute injury studies (Hay et al., 2009; Nathanson et al., 2002). Nathanson et al. (2002) reported 35% of the upper extremity injuries were to the shoulder, of which 35% were dislocations. Hay et al. (2009) reported 19 of 24 minor or moderate dislocations were to the shoulder, plus one significant shoulder dislocation. Of the 45 significant injuries reported from surfing competitions, 5 were shoulder dislocations (Nathanson et al., 2007). In a study specifically addressing shoulder injuries in professional surfers, 28% reported previous shoulder injuries including an anterior dislocation, 3 impingement syndromes and 4 cases of tendonitis. On examination, 10% of these surfers displayed Grade 1 anterior instability of the shoulder (McBride & Fisher, 2012). Shoulder injuries in surfers have been identified as being similar in type to those commonly occurring in swimmers, with shoulder impingement syndrome, acromioclavicular arthrosis and rotator cuff strains frequent in both surfers and swimmers (K. S. Taylor et al., 2006).

Back and trunk were the other frequently injured body parts accounting for 7 – 14% (Furness et al., 2015; D. Taylor et al., 2004; Woodacre et al., 2014) and 6 – 14% of injuries respectively (Hay et al., 2009; Klick et al., 2016; Nathanson et al., 2002). Additionally, Bentley et al. (2006) reported lower back injuries were the second most
frequent ACC claims. Over half (53%) of all sprains reported by Hay et al. (2009) were to the neck and back.

**Location of injury for competitive surfing.** The pattern of body parts injured differed for competitive surfers with 39% of injuries to the lower extremities, 25% to the upper extremities and only 25% to the head and neck (Nathanson et al., 2007). This is possibly due to most head and face injuries, particularly lacerations, being a result of being hit by the surfer’s own surfboard and less common in more experienced competitors, as mentioned above. Additionally, 19% of all injuries in this study were knee sprains or strains. The higher prevalence of knee injuries amongst competitive surfers is thought to be due to the more advanced skill level required for more aggressive turns and aerial manoeuvres that put more pressure through the knees (Nathanson et al., 2007).

**Location of chronic injuries.** The body parts injured in chronic injury studies exhibit different patterns from acute injuries. Common chronic injuries reported were musculoskeletal overuse and strain injuries to the shoulder and back (Furness et al., 2014; Nathanson et al., 2002; D. Taylor et al., 2004), while head and face injuries comprised only 7% of chronic injuries by Furness et al. (2014). D. Taylor et al. (2004) reported the other common body parts chronically injured were the ears. Chronic shoulder injuries were reported as 10 – 23% of injuries in surveys (Furness et al., 2014; Nathanson et al., 2002; D. Taylor et al., 2004). Furness et al. (2014) reported there were considerably more major shoulder injuries (198) versus minor injuries (23); and paddling was suggested to be responsible for causing 46% of all chronic shoulder injuries.

Spinal-region injuries were reported by D. Taylor et al. (2004) as neck and back pain or stiffness comprising 20% of chronic injuries. Overuse of the paraspinal muscles were reported by Nathanson et al. (2002) as one of the most common chronic injuries with 16% back and 9% neck. Furness et al. (2014) reported more than a third of all chronic injuries were to the back with 23% lower back and 10% neck injuries. This Australian study also revealed that competitive surfers had significantly more chronic lower back injuries than recreational surfers ($\chi^2 = 10.989, p < 0.001$) (Furness et al., 2014). Chronic lower back injuries were believed to be caused by the surfer’s own body movements, with 26% from manoeuvring on the waves and 39% from lying prone while paddling (Furness et al., 2015). Surfers have reported having spondylolysis and spondylolisthesis caused by this hyperextension of the lumbar spine while lying prone (K. S. Taylor et al., 2006). In
addition to the spinal region, the knee was the other main body part that sustained chronic injuries ranging from 8 – 12% (Furness et al., 2014; Nathanson et al., 2002; D. Taylor et al., 2004). The back leg (regardless of natural or goofy stance) may be subject to different forces compared to the front leg, but there was no significant difference for these injuries to the front or back leg reported by Furness et al. (2014).
Table 3: Location of injury

<table>
<thead>
<tr>
<th>H &amp; F</th>
<th>H &amp; N</th>
<th>H, F &amp; N</th>
<th>UEx</th>
<th>Shoulder</th>
<th>Trunk</th>
<th>Spinal</th>
<th>LEx</th>
<th>Knee</th>
<th>Ankle</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 – 41%</td>
<td>32 – 37%</td>
<td>21 – 46%</td>
<td>12 – 17%</td>
<td>5 – 16%</td>
<td>6 – 14%</td>
<td>2 – 14% LB&amp;UB</td>
<td>18 – 37%</td>
<td>11 – 16%</td>
<td>13 – 23%</td>
</tr>
</tbody>
</table>

(Refs: Moran & Webber, 2013; Klick et al., 2009; Nathanson et al., 2002; Hay et al., 2015; Klick et al., 2016; Meir et al., 2012; D. Taylor et al., 2004)

**Competition Injuries**

<table>
<thead>
<tr>
<th>25%</th>
<th>39%</th>
</tr>
</thead>
</table>

**Chronic Injuries**

<table>
<thead>
<tr>
<th>10 – 23%</th>
<th>20% - 33%</th>
<th>8 – 12%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Furness et al., 2014; Nathanson et al., 2002; D. Taylor et al., 2004</td>
<td>Furness et al., 2014; Nathanson et al., 2002; D. Taylor et al., 2004</td>
<td>Furness et al., 2014; Nathanson et al., 2002; D. Taylor et al., 2004</td>
</tr>
</tbody>
</table>

Key: H = Head; F = Face; N = Neck; UE = Upper extremities; LEx = Lower extremities.
Mechanism of injury. Being hit by a surfboard is reported as the most common cause of injuries (Dimmick et al., 2014; Moran & Webber, 2013; Nathanson et al., 2007; Nathanson et al., 2002; D. Taylor et al., 2004; Woodacre et al., 2014). D. Taylor et al. (2004) recorded 45% of acute injuries were caused by being hit by a surfboard, either the surfer’s own or someone else’s. Other studies reported over half the injuries were caused by the surfer’s own board, 50 – 58% of all injuries (Dimmick et al., 2014; Moran & Webber, 2013; Nathanson et al., 2002), while being hit by another surfer’s board was reported to be much lower at 4 – 12% (Moran & Webber, 2013; Nathanson et al., 2002; Woodacre et al., 2014).

During competitions, being hit by a surfboard was still the most frequent cited mechanism of injury but was much less at 29% (Nathanson et al., 2007). During a surfing heat only 2 to 6 surfers are in the water at any one time (Nathanson et al., 2007); which may reduce the likelihood of being hit by other surfers’ boards. In the late 1970s leashes connecting the surfboard to the surfer’s limb were introduced so the board is easily retrieved after wiping out (Dimmick et al., 2014; Nathanson et al., 2002). This may have reduced injuries from other surfers’ boards, but the elastic recoil in the leash may have also introduced potential for the board to spring back towards the surfer, and may explain at least some of the injuries from the surfer’s own board (Dimmick et al., 2014; D. Taylor et al., 2004). Leashes are now designed with less elastic recoil in an attempt to reduce these injuries (Dimmick et al., 2014). The hard materials in fins and rails causes most of the injuries from the surfer’s own board while fins and nose were responsible for most of the injuries from other surfer’s boards (Nathanson et al., 2002). Surfboard modifications of duller fins and nose guards to reduce the point of the nose have been recommended to reduce these injuries (Dimmick et al., 2014; D. Taylor et al., 2004). Despite this, it is suggested that modifications to surfboards may affect performance, and also for aesthetic reasons may not be welcomed by the surfing community (D. Taylor et al., 2004).

Riding the wave was another common mechanism of injury accounting for 37 – 62% of injuries in surveys (Furness et al., 2015; Nathanson et al., 2002). Acute injuries while riding the wave was further divided into the take-off/stand up phase (7 – 16%), turning (16 44%), tube riding (9 – 10%) and aerials (5 – 6%; when the surfer propels themselves into the air and lands back on the wave) (Furness et al., 2015; Nathanson et al., 2002). Wipe outs were also reported to cause 36% of injuries by D. Taylor et al. (2004). The surfer’s own body motion in competitions was reported to cause 16% of injuries and was rated the
third highest mechanism, which was slightly less than wave riding in other studies (Nathanson et al., 2007).

Injury from hitting the seafloor and the hydraulic force of the wave were other highly rated mechanisms of injury, ranging from 17 – 24% (Moran & Webber, 2013; Nathanson et al., 2007; Nathanson et al., 2002; D. Taylor et al., 2004; Woodacre et al., 2014), and 7 – 12% respectively (Nathanson et al., 2007; Nathanson et al., 2002; Woodacre et al., 2014). During competitions both the wave size and type of sea floor were reported to affect the risk of injury (Nathanson et al., 2007). The risk of injury by surfing over reef or rocky bottoms was 2.6 times greater than surfing over sandy bottoms (Nathanson et al., 2007). Nathanson et al. (2002) also reported significantly more injuries when surfing over reef bottoms compared to sandy (p = 0.0001). Woodacre et al. (2014) reported 15% of injuries were from coral or reef bottom, even though the majority of surfing breaks were reported as sandy and shingle bottoms which only accounted for 7% of injuries. The force of the wave was also a factor that increased injury risk during competitions with more than double the risk of injury (odds ratio = 2.4, 95%CI = 1.5 – 3.9) in bigger waves that were overhead or higher compared to waves that were head height or smaller (Nathanson et al., 2007). Nathanson et al. (2007) suggested increased risk is due to the energy of waves increasing exponentially to the wave height. An injury commonly caused by the force of the wave is rupture of the tympanic membrane (ear drum) (Nathanson et al., 2002; D. Taylor et al., 2004).

Exposure to the environment has also been reported as responsible for many injuries. Exposure to salt water and sun were reported to be responsible for chronic ear and eye injuries (Dimmick et al., 2014; Nathanson et al., 2002). Surfer’s ear, which is caused by bony growths in the ear canal and also known as auditory or bony exostosis, is believed to be caused by chronic exposure to cold water (Dimmick et al., 2014; D. Taylor et al., 2004; S. Taylor et al., 2006). Otitis externa or swimmer’s ear is also common in surfers and has multiple contributing factors including damage from stagnant water in the ear canal and trauma (D. Taylor et al., 2004; K. S. Taylor et al., 2006). D. Taylor et al. (2004) reported 46% of chronic injuries were either chronic bony exostoses (surfer’s ear) or otitis externa (swimmer’s ear) and 4.8% were eye related. Nathanson et al. (2002) reported 14% of chronic injuries were surfer’s ear. The three, chronic head and face injuries reported by Dimmick et al. (2014) were all chronic bilateral surfer’s ear. Surfers who have surfed for more than 20 years are at increased risk of developing surfer’s ear (Nathanson et al.,
with 50% increased chance for men and 43% for women (Hurst, Bailey, & Hurst, 2004). Earplugs are highly recommended to avoid the need for ear surgery in colder climates (Nathanson et al., 2002). Additionally, marine life was responsible for 3% of injuries, and included injuries caused by jelly fish, coral reef and sting ray (Nathanson et al., 2002). Skin inflammation, which included rashes, and marine and insect stings, made up 7.1% of injuries reported by Moran and Webber (2013).

Furness et al. (2014) were the only authors that reported the mechanism of injury in relation to chronic overuse type injuries (Furness et al., 2014). Paddling accounted for a total 36% of chronic injuries: 21% from prolonged paddling; 9% high intensity paddling; and 6% keeping head up while paddling. Riding the wave caused another 29% of chronic injuries: 15% from turning manoeuvres; 6% standing up phase; 2% tube riding; and 2.5% aerials (Furness et al., 2014).

**Warm ups, cool downs and conditioning training.** Only one survey reported on surfers warm-up and cool-down routines (Meir et al., 2012). Meir et al. (2012) found that 21% of surfers reported always doing some sort of warm up prior to entering the water, while only 2% performed cool down exercises post-surf-sessions. Surfers may become deconditioned due to inconsistent surf conditions with long periods of unfavourable surf (Renneker, 1987). Renneker (1987) suggested in 1987 that surfers rarely perform out of the water conditioning training for surfing, which is still likely today for many surfers. These of lack of warm ups, cool downs and out of the water conditioning training by surfers may be contributing to the reduced core strength and flexibility of surfers’ shoulders, backs and hamstrings compared to other athletes that were observed by Gillam et al., (Renneker, 1987). This lack of core strength and reduced flexibility observed in surfers may be predisposing factors for some surfing injuries.

**Conclusion**

There appears to be a need for surfing injury prevention protocols based on the growing popularity of surfing worldwide, the health benefits of surfing and the importance of surfing to many New Zealanders. A modest number of surfing injury studies, mostly set at EDs and from retrospective surveys, have investigated injury rates, injury nature and mechanisms of injury with some common inter-study conclusions. Overall, it appears that head and face injuries are the most common acute (traumatic) injury and are often
lacerations caused by being hit by a surfboard. Concussions, although rare, have often been reported as serious injuries. Protective headgear has been suggested by many studies as possibly a preventative measure for these head and face injuries, but despite this, many surfers still do not wear headgear and there is a lack of investigation to support their use. Future research may focus on exploring this concept further, especially regarding the opinions of surfers and the surfing community. Spinal injuries, especially the neck, as well as shoulder and knee injuries were also often reported as serious injuries, involving fractures or dislocations or requiring surgery. Understanding the aetiology and mechanism of these musculoskeletal injuries better may be another direction for research, along with developing preventive measures for these body parts.

Of the surfing injury research identified, only two studies were conducted in NZ (Bentley et al., 2006; Moran & Webber, 2013). The NZ Lifeguard study has limitations with the definition of surfing used, which included many other surfing-related activities such as body boarding (with a foam board) and body surfing, therefore, conclusions may not relate specifically to surfing injuries (Moran & Webber, 2013). The ACC study captured only traumatic injuries that had received medical attention (Bentley et al., 2006). Hence, gradual-onset surfing injuries and injuries that have not received medical attention in NZ do not appear to have been investigated.

Only three of the found studies have reported data specific to chronic injuries, in which the patterns of injuries appear to differ from traumatic injuries (Furness et al., 2014; Nathanson et al., 2002; D. Taylor et al., 2004). Musculoskeletal overuse and strains to shoulders and lower backs were most common, along with surfer’s ear. Only one study has investigated the mechanism of these injuries and concluded paddling and lying prone while paddling were a major cause of shoulder and lower back injuries (Furness et al., 2014). This is not surprising given the large proportion of surfing time spent with the surfer paddling in the prone position with a hyperextended lumbar spine (Farley et al., 2012b; A. Mendez- Villanueva & Bishop, 2005). The major limitation that reduces the validity of conclusions from these studies is the problematic use of the terms ‘chronic’ to define causation (rather than duration) of injuries instead using gradual-onset. Therefore, epidemiology studies about gradual-onset surfing injuries, with improved injury reporting, and studies specific to the NZ environment are still required.
References


SECTION TWO: MANUSCRIPT

Note to reader:

The manuscript in this section has been prepared in accordance with the authors instructions for the British Journal of Sports Medicine which can be accessed here [https://goo.gl/RBhuSc](https://goo.gl/RBhuSc). Unlike Section One of this thesis, which is formatted using APA 6th, the reference style in this manuscript is formatted according to instructions for British Journal of Sports Medicine. Although the recommended word count for British Journal of Sports Medicine of 3000 words and the maximum of 6 tables and/or figures has been exceeded here, for the purpose of the thesis, these guidelines will be followed for journal submission.
Abstract

Objectives
Gradual-onset injuries associated with surfing have not previously been closely examined. Therefore, the objective of this retrospective cross-sectional survey was to investigate the self-reported types, body locations, and mechanisms of gradual-onset injuries in a sample of New Zealand surfers.

Methods
Self-identified surfers currently residing in New Zealand completed an online questionnaire about gradual-onset surfing-related injuries they had experienced in the preceding 12 months.

Results
Respondents (n=1473, age range 8–78 years) reported 550 gradual-onset major injuries, of which 44% were classified as acute and 56% chronic. The crude incident rate was 1.72/1000 surfing hours, and injury prevalence was 27%. The shoulder (146 injuries, 64% chronic), lower-back (115 injuries) and neck (105 injuries) were the most commonly reported injury locations. Musculoskeletal soft tissues were the most injured structures, with 58% being muscle and tendons. Paddling was the most commonly reported mechanism of injury, particularly prolonged paddling (40% of all injuries). The injury prevalence for gradual-onset major injuries was higher for greater surfing abilities compared to lower abilities (p=0.01), and long-boarders compared to short-boarders (p=0.001). Respondents reporting any surfing injury, compared to those not, had more years surfing experience (p<0.001), were older (p<0.001), and reported surfing more hours in the preceding 12 months (p<0.001).

Conclusion
The most common gradual-onset surfing injuries were shoulder, lower back and neck musculoskeletal soft tissue injuries, most frequently arising from paddling. Long-boarding engendered greater injury risk than short-boarding. Given these findings, prospectively designed studies would be beneficial to further understand surfing injury epidemiology and to inform injury prevention initiatives.
Introduction

Surfing is a rapidly growing recreational and competitive sport. Surfing involves standing on a surfboard while riding waves as they move towards the shoreline.\(^1\)\(^2\) Surfing participation worldwide has increased by 25% since 2002,\(^3\) with recent estimates of 23 million surfers worldwide in 2016.\(^4\) Surfing was recently announced as a new sport to be introduced at the 2020 Tokyo Olympic Games.\(^5\) Many surfers consider surfing as an integral part of their lifestyle, extending into cultural, spiritual and social aspects that contribute to quality of life.\(^6\)\(^-\)\(^8\) Therefore, the impact of surfing injuries that limit participation, may cause harm to surfers because of the broad influences that surfing can have on quality of life.

Similar to Hawaii, there are reports of Māori, the indigenous people of New Zealand (NZ), surfing in the 1800s prior to European settlement.\(^9\) Surfing is still popular in NZ with surfing reported to have a higher participation rate than the perceived ‘national sport’ of Rugby Union.\(^10\) It is estimated there are more than 155,000 surfers in NZ from a population of 3.6 million adults (≥16 years).\(^10\)\(^-\)\(^11\) The Accident Compensation Corporation (ACC), a Crown entity providing no-fault insurance cover for New Zealanders, increased expenditure on surfing injury claims by 35% between 2010 and 2016 to almost NZD $5 million.\(^12\) ACC injury claims include only traumatic injuries that have been assessed by a healthcare practitioner,\(^13\) therefore gradual-onset injuries or injuries not requiring medical assistance are not included in these data.

The growing popularity of surfing, along with the consequences of surfing injuries, underpins the need to better understand surfing injury epidemiology. Most surfing injury studies have focused on traumatic injuries either presenting at emergency departments,\(^14\)\(^-\)\(^18\) using other healthcare practitioner’s reports,\(^19\)\(^-\)\(^21\) or as online surveys,\(^3\)\(^7\)\(^22\)\(^23\) and at beaches.\(^15\) Gradual-onset injury data is scarce, with the few studies that report these injuries problematically referring to them as ‘chronic’ instead of ‘gradual-onset’.\(^3\)\(^15\)\(^24\) These gradual-onset injury studies report a different pattern of involved body region compared to traumatic injuries, with sprains and strains to the shoulder, lower back and neck being the most frequently occurring.\(^3\)\(^15\)\(^24\) To date, only one gradual-onset injury study has reported the mechanism of these injuries, with paddling being the most commonly involved, especially for shoulder and spinal injuries.\(^24\) Gradual-onset injuries
have an important cost, both financially and in terms of lost participation, however, little is known about gradual-onset surfing injuries. Therefore, the aim of this study was to investigate the nature and risk of self-reported gradual-onset surfing injuries in NZ.

Methods

Design
A retrospective cross-sectional survey, delivered using an online platform (SurveyMonkey, Palo Alto, CA, USA) (Appendix A), was used to collect data on gradual-onset surfing injuries from a convenience sample of NZ surfers. Twenty participants piloted the questionnaire before it was actively promoted from December 29th, 2015 for 6 months and was closed to additional responses on July 2nd, 2016. Ethical approval was granted by the Unitec Research Ethics Committee (2015-1032) (Appendix B).

Eligibility
People who self-identified as “surfers currently in New Zealand” and were aged >8 years were invited to complete the questionnaire. Being a surfer was further established with two mandatory questions that required participants to select firstly their stance while surfing, either natural or goofy footed; and secondly the type of surfboard they predominantly used, either a short-board, mini-mal, long-board (>9 foot), or equal combination of two types of boards. Similar to Furness, et al.24 only participants who had been an active surfer for at least 12 months were included in the data analysis. Parental or caregiver approval and supervision was requested for those aged <16 years.

Questionnaire design
The questionnaire was modified from an instrument used in a recent survey of Australian surfers and was structured in two sections.22 24 Section 1 included questions about gender, age, years of surfing, and participation type: recreational surfers, defined as those who had never participated in a competition, and competitive surfers as those who had. Modifications from the Australian survey22 24 to increase relevance to the NZ context included: surfers currently residing in NZ which was defined as residing or planning to reside in NZ for at least 6 of the recent or future 12 months; time spent surfing being divided into summer and winter seasons; inclusion of surfing locations specific to NZ; and
addition of an ethnicity item matching the NZ Census, which allowed participants to select more than one ethnic group (Appendix C). An adapted version of the Hutt scale of levels was also used to improve clarity regarding surfing ability (Appendix D). Section 2 included questions about surfing-related injuries experienced in the preceding 12 months in the ‘Upper Body Region’ and ‘Lower Body Region’. Each region was further divided into 9 body parts, instead of 12 in Furness et al., (2015), and these body parts were a condensed and modified version of the Orchard Sports Injury Classification System. Respondents were required to identify injuries as being either ‘Traumatic’ or ‘Gradual’ using descriptions adapted from the definitions of Verhagen and van Mechelen. ‘Gradual’ injuries were defined as: “the symptoms (i.e. pain or discomfort) occurred gradually over time. Not one specific event caused this injury, which is aggravated by surfing. This injury may flare up and down, and be affected by the amount of surfing performed” (Appendix A). Though findings are not reported here, the definition presented for ‘Traumatic’ injuries was “there was a specific event or sudden impact that occurred while surfing just prior to any symptoms (i.e. pain)” (Appendix A).

### Data collection procedures

The survey was promoted by a dual recruitment process with the majority of participants (more than 95%) independently accessing the questionnaire online and a small minority of surfers completing the questionnaire through face-to-face interactions with the researcher at popular surf locations. Media promotion of the questionnaire included: news articles in the NZ Herald (Appendix E), Bay of Plenty Times (Appendix F), Raglan Chronicle (Appendix G) and Stuff NZ (Appendix H); adverts on the surf report site Swell Map (Appendix I); promotion through surfing related Facebook groups such as NZ Surfers Group, Ultimate Surf Bettys, board-rider clubs and community noticeboard pages (Appendix J); as well as paid Facebook advertisements on a specifically created Facebook community page for this study (Appendix K). Whenever possible, online promotion included a direct hyperlink to the questionnaire. On completion of the questionnaire respondents were able to enter a draw to win a wetsuit (Appendix L).

### Injury Definitions

After data were collected, gradual-onset injuries were categorised as ‘Minor’ or ‘Major’. Major injuries were defined as those requiring medical attention, and/or time off surfing and/or work; and minor injuries as requiring none of these. Medical attention from a
health care practitioner included going to a doctor, physiotherapist, osteopath, chiropractor, specialist and/or practitioners of traditional Māori healing. Major injuries were then further categorised as ‘Serious’ if the respondent reported staying overnight in hospital, and/or receiving surgery, and/or taking >12 months off surfing and/or work due to injury. ‘Acute’ or ‘Chronic’ injuries were categorised based on duration of time that the injury took to fully recover, or if it was still persisting at the time of completing the survey. Acute injuries were defined as those taking <3 months to recover, or starting <3 months ago and still persisting. Chronic injuries were defined as those taking >3 months to recover, or starting >3 months ago and still persisting (Appendix A).

**Data Analysis**

Based on the estimated population of 155,000 surfers in NZ, it was calculated that a minimum of 1068 respondents were required, assuming the most conservative estimated proportion of injuries (50%), a 95% confidence level and a margin of error of 3 percentage points. In order for data to be included in analysis, the ‘Surf Participation’ section and at least one injury question was required to be completed. Incomplete questionnaires were removed prior to analysis as they were considered to be from ‘false starters’, possibly due to either late recognition of ineligibility, or genuine respondents who may have restarted the questionnaire at another time.

Raw data were extracted from the online platform and sorted into gradual-onset major and minor injuries using Microsoft Excel (v.15.31). Only gradual-onset major injuries were further analysed and reported, and were summarised using frequency and descriptive statistics. Relationships between demographic, anthropometric and surfing-related independent variables and occurrence of injuries were analysed using SPSS statistical package (IBM SPSS Statistics, v.23). Chi-squared tests were used for categorical independent variables, and Mann-Whitney U test for continuous independent variables which did not meet assumptions of normality. Statistical significance was set at $p<0.05$. 
Results

Demographics
After removal of 300 questionnaires due to incomplete data, 1542 respondents completed the questionnaire. After excluding another 69 respondents who had <12 months surfing experience, 1473 respondents were included in data analysis and ranged in age from 8 – 78 years (median 34 years). Respondents were 82% male, with 98% of respondents aged >16 years and 11% of respondents >50 yrs. Nearly all respondents (99%) were currently residing in NZ predominately surfing in the North Island (86%), with almost a third surfing mostly in the Auckland region (31%). The ethnic group(s) most identified with were NZ European (85% of participants) and Māori (12%), the Māori proportion of surfers being only slightly less than the Māori proportion (15%) reported in the 2013 NZ Census.30 Most respondents (63%) were recreational surfers; the other respondents had either previously or were currently competing in local, national or international competitions. Self-perceived surfing-ability was mostly reported as ‘intermediate’ level or higher (87%) according to the Hutt scale (Appendix D). The majority of respondents (77%) predominantly surfed short-boards and 23% surfed long-boards, either in combination with another board or as just one board type (Table 4).

Total gradual-onset major injuries
Respondents reported 1046 gradual-onset surfing-related injuries experienced in the preceding 12 months, of which 550 satisfied the definition for major injury. There were 240 acute and 310 chronic major injuries; and 46 serious injuries. The shoulder was the most frequently injured body part with 146 major injuries reported (Figure 1). Of these shoulder injuries, 64% were chronic (Figure 1) and 12 were serious injuries. Diagnoses from healthcare practitioners for major shoulder injuries were reported by 104 respondents with the majority being diagnosed as rotator cuff damage and/or bursitis (n=83; Figure 2). Lower-back and neck were the second and third most common injury sites, respectively (Figure 1). When all back and neck injuries were combined, including upper back, they accounted for 46% of all major injuries. The most self-reported injured structures were musculoskeletal soft tissues, especially muscles and tendons (58% of all major injuries, 78% of major shoulder injuries), joints and ligaments (38%), and nerves (18%) (Table 1). The mechanisms that caused or aggravated the majority of injuries were
related to paddling, particularly prolonged paddling (40% of all major injuries, 79% of major shoulder injuries; Table 2).

Ears accounted for 69% of head and face injuries (Table 1). The mechanism of these injuries was often prolonged exposure to sea water (Table 2). In an additional question, 27% of respondents reported having a diagnosis by a doctor of surfer’s ear (external auditory canal exostosis) with 20% of respondents having it in both ears.
Figure 1: Total gradual-onset major injuries: acute and chronic.

Figure 2: Shoulder gradual-onset major injuries.

Diagnoses by healthcare practitioners were reported by 104 respondents for shoulder gradual-onset major injuries. Respondents could select more than one diagnosis so proportions do not equate to 100%.
Table 1: Numbers of injuries to tissue for each body part

<table>
<thead>
<tr>
<th>BODY PART</th>
<th>Shoulder</th>
<th>LB</th>
<th>Neck</th>
<th>UB</th>
<th>Knee</th>
<th>H &amp; F</th>
<th>R &amp; S</th>
<th>Arm</th>
<th>Hip &amp; Groin</th>
<th>Leg &amp; Ankle</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>MUSCULOSKELETAL SOFT TISSUE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muscle or tendon</td>
<td>115</td>
<td>55</td>
<td>76</td>
<td>20</td>
<td>7</td>
<td>1</td>
<td>8</td>
<td>16</td>
<td>13</td>
<td>9</td>
<td>320</td>
</tr>
<tr>
<td>Joint or ligament</td>
<td>50</td>
<td>50</td>
<td>34</td>
<td>10</td>
<td>33</td>
<td>10</td>
<td>9</td>
<td>10</td>
<td>4</td>
<td></td>
<td>210</td>
</tr>
<tr>
<td>Nerve</td>
<td>13</td>
<td>36</td>
<td>30</td>
<td>6</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>93</td>
</tr>
<tr>
<td>OTHER TISSUES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skin</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Bone</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>Ear</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>24</td>
<td></td>
<td>24</td>
</tr>
<tr>
<td>Eye</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Unknown</td>
<td>6</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>18</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>7</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>14</td>
</tr>
</tbody>
</table>

Key: LB=Lower-back; UB=Upper-back; H & F=Head and Face; R & S=Ribs and Sternum.

Note: Respondents could select more than one tissue per injury so totals for each body part do not equate to the total number of injuries for that body part.
Table 2: Mechanisms of injury reported for each body part

<table>
<thead>
<tr>
<th>BODY PARTS</th>
<th>H &amp; F</th>
<th>Neck</th>
<th>Shoulder</th>
<th>UB</th>
<th>R &amp; S</th>
<th>Arm</th>
<th>LB</th>
<th>Hip &amp; Groin</th>
<th>Knee</th>
<th>Leg &amp; Ankle</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PADDLING</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Keeping head up</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>70</td>
</tr>
<tr>
<td>while paddling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prolonged paddling</td>
<td>1</td>
<td>2</td>
<td>116</td>
<td>23</td>
<td>10</td>
<td>15</td>
<td>55</td>
<td></td>
<td></td>
<td></td>
<td>222</td>
</tr>
<tr>
<td>High intensity paddling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>67</td>
</tr>
<tr>
<td>Prolonged lying</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td>29</td>
<td></td>
<td></td>
<td></td>
<td>59</td>
</tr>
<tr>
<td>on surfboard</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>RIDING WAVE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standing up phase</td>
<td>19</td>
<td>13</td>
<td>24</td>
<td>7</td>
<td>15</td>
<td>6</td>
<td>84</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moving neck</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>while performing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>turning manoeuvres</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performing</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>25</td>
<td></td>
<td>5</td>
<td></td>
<td>65</td>
</tr>
<tr>
<td>turning manoeuvres</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tube riding</td>
<td></td>
<td>1</td>
<td>6</td>
<td>1</td>
<td></td>
<td></td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landing aerials</td>
<td>8</td>
<td>4</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wipe outs</td>
<td>1</td>
<td>8</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MISCELLANEOUS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prolonged sitting</td>
<td>13</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>on surfboard</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duck-diving</td>
<td>1</td>
<td>23</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td></td>
<td>1</td>
<td></td>
<td>37</td>
</tr>
<tr>
<td><strong>ENVIRONMENTAL EXPOSURE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prolonged</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>exposure to sun</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prolonged</td>
<td>23</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>23</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>exposure to sea</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>UNKNOWN / OTHERS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>3</td>
<td>16</td>
<td>11</td>
<td>3</td>
<td>5</td>
<td>20</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>69</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>5</td>
<td>9</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>36</td>
<td></td>
</tr>
</tbody>
</table>

Key: H & F=Head and Face; UB=Upper-back; R & S=Ribs and Sternum; LB=Lower-back.
Note: Respondents could select more than one mechanism of injury so totals for each body part do not equate to the total number of injuries for that body part.
Incident rate and prevalence

Incident rate (IR) was calculated as the total number of gradual-onset major injuries (n=550) for the preceding 12 months, divided by the total hours surfed by all respondents over the same period. The crude IR for this study was 1.72 gradual-onset major injuries per 1000 hours of surfing. Injury prevalence (IP) was calculated as the number of respondents with gradual-onset major injuries (total n=405) for the preceding 12 months, divided by the number of respondents (total n=1473). The total IP for gradual-onset major injuries over the preceding 12-month period was 27% of the sample.

Injury risk factors

Surfing ability-levels and competitive versus recreational surfers

The proportion of gradual-onset major injuries differed between self-perceived surfing ability-levels (p=0.01; Table 3), with higher ability-levels associated with greater IP. There was no difference in IP between competitive and recreational surfers (p=0.053; Table 3). Respondents with higher surfing ability-levels had higher IP for lower-back injuries than those of lower ability-levels (p<0.001; Table 3). Also, respondents who were advanced or expert level (combined) had higher IP of neck injuries (p=0.027; Table 3) compared to beginner or intermediate (combined). There were also higher IP for competitive versus recreational surfers for lower-back (p=0.005; Table 3), neck (p=0.018; Table 3), and shoulder injuries (p=0.016; Table 3). There was no difference in IP between surfing ability-levels and all other body parts. There was also no difference in IP between respondents who could complete aerial manoeuvres (14% of participants) and those who could not, and no difference in IP for knee injuries between respondents who could and who could not complete aerial manoeuvres.
Table 3: Comparison of injury prevalence between surfing ability-levels, and competitive status.

<table>
<thead>
<tr>
<th>Surfing ability-level and competitive status</th>
<th>Beginner</th>
<th>Intermediate</th>
<th>Advanced</th>
<th>Expert</th>
<th>p</th>
<th>Total Surfers</th>
<th>Recreational</th>
<th>Competitive</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>n=194</td>
<td>n=445</td>
<td>n=538</td>
<td>n=296</td>
<td>n=1473</td>
<td>n=931</td>
<td>n=542</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injured surfers</td>
<td>46</td>
<td>107</td>
<td>150</td>
<td>102</td>
<td>0.01</td>
<td>405</td>
<td>240</td>
<td>165</td>
<td>0.053</td>
</tr>
<tr>
<td>(IP)</td>
<td>(23.7%)</td>
<td>(24.0%)</td>
<td>(27.9%)</td>
<td>(34.5%)</td>
<td>(27.5%)</td>
<td>(25.8%)</td>
<td>(30.4%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower-back</td>
<td>7</td>
<td>17</td>
<td>49</td>
<td>34</td>
<td>&lt; 0.001</td>
<td>107</td>
<td>54</td>
<td>53</td>
<td>0.005</td>
</tr>
<tr>
<td>(3.6%)</td>
<td>(3.8%)</td>
<td>(9.1%)</td>
<td>(11.5%)</td>
<td></td>
<td></td>
<td></td>
<td>5.8%</td>
<td>9.8%</td>
<td></td>
</tr>
<tr>
<td>Neck</td>
<td>32</td>
<td>66</td>
<td>0.027</td>
<td>98</td>
<td>51</td>
<td>47</td>
<td>0.018</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(5%)</td>
<td>(7.9%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(5.5%)</td>
<td>(8.7%)</td>
<td></td>
</tr>
<tr>
<td>Shoulder</td>
<td>58</td>
<td>83</td>
<td>0.571</td>
<td>141</td>
<td>76</td>
<td>65</td>
<td>0.016</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(9.1%)</td>
<td>(10.0%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(8.2%)</td>
<td>(12%)</td>
<td></td>
</tr>
<tr>
<td>IR</td>
<td>2.1</td>
<td>1.7</td>
<td>1.3</td>
<td>1.72</td>
<td>1.9</td>
<td>1.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean hours</td>
<td>141</td>
<td>232</td>
<td>352</td>
<td>217</td>
<td>286</td>
<td>177</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key: IP=Injury prevalence (injured surfers/total surfers; % of respondents injured for each category); IR=Incident rate.

a = Total number of respondents who self-reported being a beginner-level surfer.
b = (Injury prevalence).
c = Beginner and intermediate levels combined total of injured surfers and IP (for neck, shoulder, IR and mean hours).
b = Advanced and expert levels combined totals of injured surfers and IP (for neck and shoulder).
Board types: long-boards versus short-boards

Respondents who surfed long-boards had higher IP compared to those who surfed other types of surfboards \((p=0.01;\) Table 4). The IP was higher for long-boarders when compared with only short-boarders \((p=0.001)\). When respondents reported surfing with both short-boards and mini-mals, or combining long-boards with mini-mals, this did not make any difference to the IP compared to using only short-boards, or long-boards respectively.

The IP of the shoulder was higher for long-boarders compared to short-boarders \((p=0.001)\), and this was also not affected when mini-mals were used in combination. There was no difference in IP between board types for lower-back, upper back, ribs and sternum, hip or knee injuries.

Table 4: Comparison of injury prevalence between injured and non-injured surfers considering board types predominantly used.

<table>
<thead>
<tr>
<th>Board Types</th>
<th>SB</th>
<th>MM</th>
<th>LB</th>
<th>LB/SB</th>
<th>SB/MM</th>
<th>LB/MM</th>
<th>Total</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n=919(^a)</td>
<td>n=137</td>
<td>n=172</td>
<td>n=132</td>
<td>n=84</td>
<td>n=29</td>
<td>n=1473</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injured surfers</td>
<td>236</td>
<td>32</td>
<td>66</td>
<td>39</td>
<td>21</td>
<td>11</td>
<td>405</td>
<td>0.01(^c)</td>
</tr>
<tr>
<td>(25.7%)(^b)</td>
<td>(23.4%)</td>
<td>(38.4%)</td>
<td>(29.5%)</td>
<td>(25.0%)</td>
<td>(37.9%)</td>
<td>(27.5%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder injury</td>
<td>73</td>
<td>10</td>
<td>28</td>
<td>16</td>
<td>9</td>
<td>5</td>
<td>141</td>
<td>0.008(^c)</td>
</tr>
<tr>
<td>(7.9%)</td>
<td>(7.3%)</td>
<td>(16.3%)</td>
<td>(12.1%)</td>
<td>(10.7%)</td>
<td>(17.2%)</td>
<td>(9.6%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key: SB=Short-board; MM=Mini-mal; LB=Long-board; / =equal combination of two types of board.
\(^a\) = Total number of respondents who reported predominantly using short-boards.
\(^b\) = (Injury prevalence).
\(^c\) = Reported \(p\) value calculated from Chi-squared across six board types/combinations between injured and non-injured surfers.

Other risks

Injured respondents had more years surfing experience \((p<0.001)\), were older \((p<0.001)\) and spent more hours surfing in the preceding 12 months \((p<0.001)\) (Table 5).

Respondents with shoulder, lower-back and neck injuries were also older and had more years surfing experience (Table 5). More hours surfing was reported by respondents with shoulder and lower-back injuries but not neck injuries (Table 6). Injured respondents were
also taller ($p=0.007$) and heavier ($p=0.0007$); although there was no risk difference relative to body mass index. There was no difference in IP between genders, goofy or natural footed surfers, or between respondents surfing in the North or South Island.

Table 5: Comparisons between injured and non-injured surfers for hours of surfing exposure, age and years of surfing experience.

<table>
<thead>
<tr>
<th></th>
<th>Hours surfing for whole year</th>
<th>Age (years)</th>
<th>Years surfing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injured</td>
<td>164 (41 – 287)</td>
<td>36 (29 – 44)</td>
<td>18 (8 – 28)</td>
</tr>
<tr>
<td>Non-injured</td>
<td>117 (8 – 226)</td>
<td>33 (25 – 41)</td>
<td>13 (3 – 23)</td>
</tr>
<tr>
<td>$p$</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Notes: All values are median (interquartile range).

Table 6: Comparisons between injured and non-injured surfers for hours of surfing exposure, age and years of surfing experience considering shoulder, lower-back and neck.

<table>
<thead>
<tr>
<th></th>
<th>Hours surfing for whole year</th>
<th>Age (years)</th>
<th>Years surfing</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHOULDER</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injured surfer</td>
<td>182 (61 – 304)</td>
<td>38 (30 – 47)</td>
<td>18 (6 – 31)</td>
</tr>
<tr>
<td>Non-injured</td>
<td>128 (17 – 239)</td>
<td>34 (27 – 42)</td>
<td>13 (6 – 21)</td>
</tr>
<tr>
<td>$p$</td>
<td>0.043</td>
<td>&lt; 0.001</td>
<td>0.006</td>
</tr>
</tbody>
</table>

| LOWER-BACK     |                             |             |              |
| Injured        | 208 (69 – 348)              | 37 (31 – 44) | 18 (8 – 28)  |
| Non-injured    | 128 (17 – 239)              | 34 (26 – 42) | 13 (5 – 21)  |
| $p$            | <0.001                      | 0.008       | <0.001       |

| NECK           |                             |             |              |
| Injured        | 145 (23 – 267)              | 37.5 (31 – 44) | 23 (11 – 36) |
| Non-injured    | 130 (16 – 244)              | 34 (15)      | 13 (3 – 23)  |
| $p$            | 0.427                       | <0.001      | <0.001       |

Notes: All values are median (25th percentile – 75th percentile).
Discussion

Common injuries and mechanism
The findings of this retrospective study confirm the importance of gradual-onset surfing injuries in NZ, especially to body areas affected by paddling. Consistent with the few previous gradual-onset injury studies, strains and sprains to the shoulder, lower-back and neck were the most frequent major injuries reported.\textsuperscript{3,15,24} Here, 27\% of all injuries involved the shoulder, 21\% lower-back and 19\% neck injuries, representing higher proportions than in previous gradual-onset studies which reported 10 – 13\% shoulder and 20 – 33\% back and neck injuries.\textsuperscript{3,15,24} In contrast to the substantial risk of shoulder gradual-onset injuries, shoulder-region injuries represent only 5 – 16\% of traumatic surfing injuries.\textsuperscript{15,16,22,23}

The primary mechanism for gradual-onset injuries was paddling. In the present study prolonged paddling caused 40\% of all injuries and also caused a high proportion of shoulder injuries overall (79\%), similar to 81\% reported by Furness, et al.\textsuperscript{24} Approximately 50\% of a surf session has been reported to be spent paddling and this may explain paddling as the main mechanism of shoulder injuries.\textsuperscript{32-34} Additionally, surf sessions are typically 2 hours in length,\textsuperscript{7} but may, when conditions are favourable, extend to 4 – 5 hours per day.\textsuperscript{2,35} Therefore, physical demands from paddling may be high.\textsuperscript{2}

Paddling-related activities were also the most common mechanism for most lower-back and neck injuries. Prolonged paddling was the mechanism reported for 48\% of lower-back injuries and lying prone on the surfboard for 25\%, similar to previous findings by Furness et al. who reported 39\% for both.\textsuperscript{24} Keeping the head up while paddling caused 67\% of neck injuries here, with a slightly greater proportion, 79\%, reported by Furness, et al.\textsuperscript{24} These mechanisms of lower-back and neck injuries can also be explained by the high proportion of surfing time spent paddling, as during this time surfers hyperextend their lower-back and neck while looking forward and lying in the prone position.\textsuperscript{2} Constant trunk hyperextension may exacerbate muscle imbalances, and Gillam et al. (1986) reported surfers have less abdominal strength and reduced back and hamstring flexibility compared to other athletes.\textsuperscript{36}
Gradual-onset versus chronic injuries

Higher proportions of shoulder and spinal injuries reported here, compared to previous gradual-onset studies, may be due to variations in injury definitions between studies. These variations, which create general difficulties for inter-study comparisons, arise through interchangeable use of ‘Gradual-onset’ and ‘Chronic’ to describe injuries. Recommended definitions for these terms were applied in this study, but have not been universally adopted previously. Here, ‘Gradual-onset’ describes injury causation (opposite of ‘Traumatic’), and is defined as “caused by repeated micro-trauma without evidence of a single, identifiable event”. The term ‘Chronic’ was used in reference to injury duration (opposite of ‘Acute’), and is defined as “pain which persists past the normal time of healing”. This time-frame may vary depending on tissue type and injury severity, but in this study, was defined as being present for >3 months, in common with other musculoskeletal studies. In this study both gradual-onset acute and gradual-onset chronic injuries were distinguished, and to the author’s knowledge this is the first study to report gradual-onset acute surfing injuries. Failure to consider the duration of gradual-onset injuries or to include only injuries present for >3 months could be considered limitations of previous studies in the area. Approximately half the major gradual-onset injuries in this study were acute (44%) as they were reported to recover within 3 months of symptoms starting, particularly for the lower-back (42%) and neck (54%). These findings illustrate that even though injuries may begin gradually, they may not be long-term burdens. In previous surfing studies these gradual-onset acute injuries were either not reported, or there may have been confusion for respondents as whether to report them as acute (traumatic) or gradual-onset (chronic) injuries.

The proportion of gradual-onset acute shoulder injuries, although lower (37%) than lower-back and neck injuries, were still substantial and may explain the larger proportion of injuries identified here compared to previous studies. Cools, et al. suggest early detection and appropriate management for athletes with vague shoulder symptoms may improve outcomes. In this study, 56% of respondents with gradual-onset acute shoulder injuries reported consulting healthcare practitioners, including manual therapists. The recovery time for the 44% of gradual-onset acute shoulder injuries that medical attention was not sought for, may have been influenced by other factors such as alternative forms of therapy for which the effects are unknown. The nature and level of other physical activity undertaken by surfers might also impact injury recovery, such as participation in other
sports or physical training including yoga or Pilates, warm up and cool down before or after surf sessions, or different work types such as office work or manual labour. Additionally, overuse gradual-onset shoulder injuries may predispose surfers to traumatic injuries due to existing micro-trauma, for example shoulder dislocations which have been reported as common serious traumatic injuries. Therefore, preventing and improving recovery for gradual-onset shoulder injuries, may also reduce the risk of traumatic shoulder injuries in surfers.

The influence of surfing-related variables on surfing injury risk

There were differences between injured and non-injured surfers for age, hours surfing, years surfing, surfing ability-levels, and board type. The effects of these variables have been analysed here individually, but they may be inter-related and further multivariate analysis could be useful to further explore these relationships.

Years of surfing and surfers age

Injured surfers had surfed for an average of 5 more years, and were 4 years older than those non-injured, and of similar magnitude to the 5.4 years difference noted in Australian surfers of similar age. There was also an increased injury risk for shoulder, lower-back and neck for both older surfers and those with more years surfing experience. This may be due to age-related soft-tissue change and the cumulative overuse effects of more time surfing over years contributing to gradual-onset injuries.

Hours of surfing

There were also more hours surfed by those injured, compared to those non-injured, with a difference of medians of almost 50 hours (40%) more in the previous year, including respondents with shoulder (42% more hours) and lower-back injuries (63% more hours). This may be explained by the recent cumulative overuse effect of more surfing in the preceding 12 months. Improvements in wetsuit designs protect the surfer from colder water and allow longer sessions of participation across the seasons, which in turn may contribute to injuries resulting from overuse, particularly to the shoulder, lower back and neck. In NZ, wetsuits are worn year-round by most surfers, with NZ water temperatures varying in summer from 13 – 21°C from South to North and during Winter ranging from 9.5 – 16°C. In contrast, Furness, et al. reported no difference in gradual-onset injury risk according to hours surfed, which may be related to many surfers in Australia surfing in
much warmer waters, where wetsuits are not required year round. Also, the link between hours surfed and injuries reported here may result from the separate identification of hours surfed during summer and winter seasons, which may cause variations when compared to hours surfed being reported as an average for the entire year by Furness, et al.24

**Influence of lack of out of water training contributing to injuries**
Although these practices were not assessed in the current survey, the role of warming up, cooling down and limited conditioning training performed by surfers may be other variables that also contribute to gradual-onset injuries.7 36 Stovitz and Johnson argue that lack of training or inactivity may predispose these injuries, rather than injuries being simply caused by an ‘overuse’ of body parts.28 46 Inconsistent surf conditions that often result in long periods of unfavourable surf and associated deconditioning of surfers may also be partly responsible for the common occurrence of gradual-onset injuries.36

**Injury risk across surfing ability-levels and competitive status**
This study showed an increased injury risk with increasing self-perceived surfing ability-levels, and is the first study to investigate this link. There were also higher IR for lower-back and neck injuries for higher-level surfers, but not shoulder injuries. There was also a trend towards more injuries overall for competitive versus recreational surfers, with increased injury risk in competitive surfers for shoulders, lower-back and neck. Furness, et al. also reported an increased risk of lower-back injuries for competitive versus recreational surfers, despite a contrasting increased overall gradual-onset injury risk for recreational versus competitive surfers.24 In traumatic injury studies, an increased injury risk for competitive surfers may be due to attempting more technically demanding manoeuvres that occur during and in preparation for competition,22 however risk-taking is less likely to be a contributing factor for gradual-onset injuries. The increased gradual-onset injury risk linked to increased surfing ability-level observed here may be explained by the effect of more years surfing that is often required to attain an advanced or expert level.

The IR for surfing ability-levels decreased as ability-level increased, and was less for competitive compared to recreational surfers as well. Although the proportion of injuries increased with ability-level and with competitive participation, it appears that increased surfing ability-level and/or participation in surfing competitions may reduce risk of
gradual-onset injury when adjusted for hours surfed. The associated practices involved in competitive surfing such as better technique, warm-up/cool-down or improved conditioning practices are possibly protective of injury.

**Injury risk for long-boarders versus short-boarders**

Interestingly, long-boarders had increased injury risk than short-boarders, in particular shoulder injuries, irrespective of whether respondents used these types of boards in equal combination with mini-mals. This observation of greater shoulder injury risk for long-boarders tends not to support a prediction over 30 years ago by Lowdon, et al. of more shoulder impingement injuries due to smaller surfboards with lower flotation requiring higher elbow movements during the paddling recovery phase. In contrast, a possible explanation for more injuries from surfing long-boards may be due to their greater buoyancy than short-boards. This greater buoyancy of long-boards can be an advantage requiring less paddle power on long-boards to catch waves which sometimes results in a preference to use long-boards instead of short-boards by surfers with reduced paddling power, either from aging, perceived deconditioning following a surfing hiatus, or lower ability-level surfers. Interestingly, though lower-back injury rates were not significantly different between board types, the opposite may have been expected if the increased shoulder injury risk for long-boarders was due to the older age of these surfers and/or more years surfing.

The greater buoyancy of long-boards can cause difficulties duck-diving so often an alternative technique called turtle-rolling is used, which entails pulling the board towards the surfer’s body while rolling upside down as the wave passes over top. Occasionally the wave forcefully pulls the long-board from the surfer’s grip while turtle rolling which may transfer the wave’s force to the surfer’s shoulders causing adverse soft-tissue strain. Despite this theory, only 2 of 28 long-board shoulder injuries were reported to be caused by duck-diving. Although, an additional theory is this shoulder strain during turtle rolling may only become noticeable to the surfer as cumulative strain occurs while paddling.

Additionally, also in contrast to the prediction by Lowdon, et al. a higher elbow angle with more shoulder abduction may be required to avoid hitting the rails on long-boards, which are often wider than short-boards, during both the power and recovery phase of paddling. Investigating the upper limb joint angles and kinematics during paddling on
different boards would be useful to help establish whether any link exists between paddling technique and gradual-onset shoulder injuries.

**Shoulder injuries**

**Shoulder impingement syndrome**

Rotator cuff damage and/or bursitis were reported by 83 surfers (80% of respondents with shoulder diagnoses) as the most common shoulder diagnoses obtained from healthcare practitioners. These results were not surprising since athletes using overhead arm movements often experience shoulder impingement syndromes, and rotator cuff damage and bursitis are common pathologies of this syndrome.\(^\text{41}\) Similar to freestyle swimmers, surfers repeatedly reach over head during the recovery phase of paddling while their glenohumeral joints (shoulders) are abducted and externally rotated.\(^\text{47}\) This is followed by the power phase when the shoulder is adducted and internally rotated against water resistance.\(^\text{47}\) The rotator cuff acts as a dynamic shoulder stabiliser, and the repetitive and narrow variation of shoulder movements during paddling may create rotator cuff muscle imbalances leading to anterior translation of the humerus head which,\(^\text{47}\) along with shoulder instability and scapular dyskinesia, may cause impingement syndromes.\(^\text{41, 47}\) Similar diagnoses were reported by McBride and Fisher from physical shoulder examinations by healthcare practitioners of 30 professional surfers, including 8 cases of scapula-winging during shoulder abduction (scapula dyskinesia), 2 impingement syndromes and 3 cases of Grade 1 anterior instability.\(^\text{43}\) These findings, which have greater diagnostic validity than self-reported surveys, illustrated 43% of this small sample of professional surfers already had shoulder impingement syndromes, or had predisposing risk factors. A larger study to investigate the prevalence of shoulder dysfunction amongst surfers is recommended.

**Study limitations**

**Recall bias**

A limitation in this study, and other retrospective surfing surveys,\(^\text{7, 15, 22, 24}\) is bias when respondents may inaccurately recall injuries and hours surfed from the preceding 12 months. This is due to potential respondent memory decay.\(^\text{48}\) Additionally, the ability to recall injuries sustained in the past 12 months is suggested to be 100%, but recall accuracy declines to 61% when more detailed information is required such as injury details and hours of participation.\(^\text{49}\) Over-estimation of participation hours is another common issue in
sports injury surveillance studies.50 Also, a further threat of recall bias in surfing is that surfing hours often change weekly due to lack of regular weekly surfing routines with no scheduled training practices or competitions as occurs in many sports, and variations in the length and number of surf sessions due to inconsistent surf conditions. This reduces the validity of an overall IR in this study for comparison with other sports, and may only be relevant for comparison of surfing hours between study respondents as most surfers would have the same difficulties with these estimates. Prospective surfing studies are required to obtain accurate estimates of IR for surfing injuries to compare to other sports.

Respondent bias
Another common limitation with the majority of previous observational research on surfing injuries is respondent bias towards injured surfers versus non-injured surfers. This survey was called ‘Surfing Injuries NZ’, which may have inadvertently encouraged more injured surfers to participate than non-injured surfers (Appendix A). This limits the validity of IP of 27% reported in this study and may not be a true representation of surfing injury prevalence in the NZ surfing population. This study attempted to reduce limitations of respondent bias by making it clear to surfers that they did not need to be injured to complete the questionnaire. These statements were included in promotions of the survey on social media and other public media: “seeking all surfers currently in NZ” (Appendix I) and, “…you do not need to be injured to complete this survey” (Appendix K).

Future study recommendations
The finding of elevated risk of gradual-onset shoulder injuries in surfing, along with the findings by McBride and Fisher that poor shoulder movement control and shoulder injuries may be common in surfers,43 highlights the need for a larger study using physical shoulder examinations by musculoskeletal practitioners to investigate the prevalence of risk factors for shoulder dysfunction. Also, a prospective longitudinal case series is recommended to investigate factors influencing recovery time for shoulder gradual-onset injuries as well as traumatic shoulder injury rates (such as shoulder dislocations) for surfers who had previous gradual-onset shoulder injuries compared to those with no previous shoulder symptoms. Similar studies are also recommended for lower-back and neck gradual-onset injuries. Results from these future studies may guide designs for injury prevention and rehabilitation initiatives for surfers, including paddling technique variations, appropriate physical conditioning training programmes and clinical practice
Conclusion

In this observational, retrospective study of NZ surfers, musculoskeletal soft tissue injuries of the shoulder, followed by lower-back and neck were the most common gradual-onset injuries. The mechanism of paddling, especially prolonged paddling while lying prone was responsible for most injuries, particularly shoulder injury. Shoulder impingement syndromes were the most commonly reported diagnoses for shoulder injury. Long-boarders also had more shoulder injuries than short-boarders. Higher ability-level surfers had more injuries than lower level surfers, although this may be due the effect of increased age and more years surfing which also increased the risk of injury. Approximately half these gradual-onset injuries were acute, therefore, only half these injuries become a long-term burden as a chronic injury. Acute gradual-onset injuries may have been missed in past studies because of the inappropriate use of the term “chronic” to imply a gradual-onset of injury. Reducing the long-term burden of gradual-onset injuries should be an aim for future injury prevention research which may begin with investigations into factors influencing injury duration. Overall, prospective surfing injury research will be beneficial, with recommendations for studies to examine shoulder mechanics, as well as observing paddling techniques, particularly between board types, and their effects of subsequent injuries for surfers.
Key Findings

- This study reports the prevalence and nature of all gradual-onset surfing injuries, including those with an acute and chronic duration.
- Musculoskeletal soft-tissue shoulder, lower-back and neck were the most common type and location of gradual-onset major injuries.
- Paddling was the mechanism of most gradual-onset major injuries, especially prolonged paddling, which was an attributed cause of 79% of shoulder injuries.
- Long-boarders had a higher injury prevalence compared to short-boarders.
References


Available from:


http://scholarworks.bgsu.edu/ijare/vol7/iss3/3


42. Gregory PL. "Overuse" - an overused term? Brit J Sport Med. 2002;36(2):82-83. doi:10.1136/bjsm.36.2.82


SECTION THREE:
APPENDICES
Appendix A

Note: The questionnaire was administered using an online survey application and included considerable amount of logic ('piping'). As a printed document, the questionnaire extends to >150 pages and therefore, for convenience can be downloaded as a PDF from this link: https://goo.gl/jDt7Xw

Banner at the top of the ‘Surfing Injuries NZ’ questionnaire on the online platform SurveyMonkey.
Appendix B

Ethics letter of approval (2015-1032) for this study from Unitec Research Ethics Committee.

Dear Debbie,

Your file number for this application: 2015-1032
Title: Epidemiology of musculoskeletal surfing injuries in New Zealand.

Your application for ethics approval has been reviewed by the Unitec Research Ethics Committee (UREC) and has been approved for the following period:

Start date: 22.7.15
Finish date: 22.7.16

Please note that:

1. The above dates must be referred to on the information AND consent forms given to all participants.
2. You must inform UREC, in advance, of any ethically-relevant deviation in the project. This may require additional approval.

You may now commence your research according to the protocols approved by UREC.
We wish you every success with your project.

Yours sincerely,

Sara Donaghey
Deputy Chair, UREC

cc: Catherine Bacon
Cynthia Almeida
### Appendix C

NZ Census of Population and Dwelling form 2013 with example of ethnicity question used in questionnaire (question number 11).

![New Zealand Census of Population and Dwellings](image)

**Individual Form**

**Tuesday 5 March 2013**

For census online go to www.census.govt.nz

- [Call the Helpline toll-free on 0900 CENSUS (0800) 236 787]

<table>
<thead>
<tr>
<th>Sample</th>
</tr>
</thead>
</table>

1. **How to answer**
   - Mark your answers like this: 
   - 1 or 2, 3 or 4 5 or 6

2. **What is your full name?**
   - Forename
   - Surname

3. **Are you?**
   - Male
   - Female

4. **When were you born?**
   - Day
   - Month
   - Year

5. **Where do you usually live?**
   - Students and overseas visitors see the Guide Notes for more information.
   - Find the full address of that dwelling. Give all of these, if possible:
   - Street number
   - Street name
   - Suburb or town locality
   - City, town or district
   - Country

6. **How long have you lived at the address you gave in question 1?**
   - Less than one year or number of years

7. **Where did you usually live 5 years ago?**
   - Not born 5 years ago at the address given in question 1 or 2.
   - Print the address or fully if you can:
   - Street number
   - Street name
   - Suburb or town locality
   - City, town or district
   - Country

8. **Which country were you born in?**
   - New Zealand
   - Australia
   - England
   - China (People’s Republic of)
   - India
   - South Korea
   - France
   - Germany
   - Cook Islands
   - Please print the present name of the country

9. **If you have lived in New Zealand for 10 years or more, answer this question.**
   - What did you last come to live in New Zealand?
     - Date of arrival
     - Reason

10. **Which ethnic group do you belong to?**
    - You are asked to identify yourself:
    - New Zealand European
    - Maori
    - Mestizo (Mixed)
    - Chinese
    - European
    - Indian
    - Other
    - Other: [Please specify]

11. **If you have lived in New Zealand a hundred years or more, answer this question.**
    - Go to the back page or go to exclude.
Appendix D

Hutt Scale: Rating skill levels of surfers. Ratings are independent of surf break quality or the degree of difficulty of waves (Hutt, Black, & Mead, 2001).

1. Beginner surfers not yet able to ride the face of a wave and simply moves forward as the wave advances.

2. Learner surfers able to successfully ride laterally along the crest of a wave.

3. Surfers that have developed the skill to generate speed by ‘pumping’ on the face of the wave.

4. Surfers beginning to initiate and execute standard surfing manoeuvres on occasion.

5. Surfers able to execute standard manoeuvres consecutively on a single wave.


7. Top amateur surfers able to consecutively execute advanced manoeuvres.

8. Professional surfers able to consecutively execute advanced manoeuvres.

9. Top 44 professional surfers able to consecutively execute advanced manoeuvres.

10. Surfers in the future

Exposing the injuries beneath the waves
5:00 AM Tuesday Feb 16, 2016

Student and surfer Debbie Remnant says her project to understand surfing injuries is a “real passion”.

Surfer and Unitec osteopathy student Debbie Remnant has begun a research project to gain a better understanding of the physical toll of surfing in New Zealand. Photo / Jwan Milek

Shining a light on the hidden physical toll of wipe-outs and other surfing injuries is the aim of a first-of-its-kind Kiwi study. While statistics tell us that just as many Kiwis surf as play rugby, surprisingly little is known about the injuries that come with riding waves. That's despite the Accident Compensation Corporation spending millions each year on thousands of surfing-relating injuries. Raglan surfer Debbie Remnant now hopes to lift the lid with a nationwide research project she's leading as part of her osteopathy studies at Auckland's Unitec. "The motivation behind the whole study is to prevent surfing injuries, especially musculoskeletal injuries," she said. "But before we can do any research like that we first have to identify what the problem is here in New Zealand."

She knew otherwise fit and healthy surfers who were carrying serious or chronic injuries.

"I've got friends in their late 20s and early 30s, some competitive surfers and others
recreational surfers, who are having shoulder and hip operations due to surfing-related injuries."

Through a survey of 1500 people, she's keen to pinpoint what injuries surfers are suffering and the circumstances around them. She said traumatic injury might occur while riding the face of a wave, duck-diving (sinking the board under the water) or getting in or out of the water. Years of paddling through swells could also lead to overuse injury.
"Surfing is often not an organized sport - generally there's no coach, no regular training or anything like that," she said. "Warm-ups and warm-downs don't really happen that much. You just go when the surf's good."

Ms Remnant said she considered the project a "real passion" and felt the study might result in new measures to prevent chronic injuries. "Most surfers I know want to surf until they're at least 80 - it's not a sport you retire from when you're 30, it's a regular part of our life."

Surfers can complete the survey at surfinginjury.co.nz, via the Surfing Injuries NZ Facebook page or at swellmap.co.nz.

Debbie Remnant. Photo / Supplied

Wipe-Outs
• There are an estimated 145,000 surfers in New Zealand.
• Surveys have shown 4.5 per cent of adults and 65 per cent of high school students have surfed in the previous year.
• ACC spends almost $5 million on surfing injury claims each year.
• Between July 2013 and June 2014, there were more than 5200 ACC claims for surfing.

Appendix F

Bay of Plenty Times newspaper article printed February 6, 2016.

Kara and Lea and Daniel.

Study of surfing injuries

Surfer and Unitec osteopathy student Debbie Remnant is undertaking a research project designed to build a better understanding of the physical toll of surfing. She is aiming to identify what kinds of injuries surfers are suffering and the circumstances in which they occur. She is looking for 1000 surfers of all ages and abilities to complete an online survey about what ails them. Find the survey at www.swellmap.co.nz.
Appendix G

Raglan Chronicle newspaper article, “Raglan student’s study aims to help keep surfers up and riding’ by Edith Symes published online and printed on March 17, 2016.

Raglan student’s study aims to help keep surfers up and riding

When it comes to surfing Raglan osteopathy student Debbie Remnant stands by the old adage that prevention is better than cure. So she’s “excited” to have already more than 900 of the 1500 responses she needs by June to complete her online survey of surfers’ injuries which – when analysed – will contribute to the development of injury prevention protocols for osteopaths and physiotherapists, surf coaches, yoga and pilates instructors internationally.

“They will be able to utilise this information in dealing with surfers as opposed to non-surfers,” Debbie says of the first-of-its-kind Kiwi study she’s leading as part of her master’s thesis at Auckland’s Unitec.

Debbie, 35, is well suited to undertaking such surfing-specific research, having lived in Raglan and worked at Whale Bay’s surfing school as both a surf and more recently a yoga instructor on-and-off for several years.

She says she knows many otherwise fit and healthy people from the surfing community who are carrying serious or chronic injuries. “Injuries are prevalent among my surfing friends and anecdotally it seems that serious preventable surfing injuries are on the rise.

“When I’m in Raglan and especially since I started osteopathy (after first doing a sports studies diploma) the topic will come up often … I’ve got friends in their late 20s and early 30s, some competitive surfers and others recreational surfers, who are having shoulder and hip operations due to surfing-related injuries.”

She’s keen now to pinpoint through analysis of the data she’s gathered since December exactly what these injuries are and how they happened. A shoulder problem, for instance, might be the result of a body position or posture peculiar to surfers. “And prevention is better than cure,” she insists.

The survey asks about traumatic and gradual overuse injuries and the circumstances around how those injuries presented.

A traumatic injury might occur when a surfer is riding the face of a wave, duck-diving or getting in or out of the water, Debbie explains, while a gradual overuse injury could be the result of continuous paddling and develop over time. Different injury patterns are already emerging, she adds, based on demographics such as gender – close to 200 females have completed the survey – and whether participants are new or advanced surfers.

Debbie says the project’s a “real passion” and hopes it might result in new measures to prevent chronic injuries. She points out that while statistics tell us almost as many Kiwis surf as play rugby,
surprisingly little is known about injuries that come with riding waves. And the fact that surfers do not participate in their sport the way others play theirs – no coach, no training, often no warm-ups or warm-downs – could well contribute to some injuries.

“Most surfers I know want to surf until they’re at least 80,” says Debbie. And that’s motivation enough to research what she believes are preventable injuries.

*Surfers can complete the survey at surfinginjury.co.nz, via the Surfing Injuries NZ Facebook page or at swellmap.co.nz.*

Edith Symes
http://raglan.net.nz/2016/03/17/raglan-students-study-aims-to-help-keep-surfers-up-and-riding/
Appendix H

Stuff NZ/Fairfax NZ article ‘Unitec research project exposing surfing injuries’ by Alastair Lynn published online on March 14, 2016.

Unitec research project exposing surfing injuries
ALASTAIR LYNN
Last updated 12:43, March 14 2016

Surfer and Unitec osteopathy student Debbie Remnant is conducting research to better understand injuries prone to surfers.

Battling pounding waves and fierce surf can put an enormous strain on the body. ACC spends almost $5 million of dollars every year on surfing related injuries, yet little is known about how they occur.

Unitec osteopath student Debbie Remnant hopes to wash away the unknown with a nation-wide research project to understand the physical toll of surfing.

Thousands of surfers hit the waves every day but Remnant says injuries are not always obvious at first.

"Because it's not a mainstream sport you don't really get that scientific interest and research demand," she says.

"Things that begin as little niggles can get progressively worse over a long period of time. "The ultimate goal is to prevent these injuries and people needing to get surgery when they're young. It's preventable."

Remnant hopes to pinpoint the root causes of both traumatic and gradual injuries through a survey of 1500 surfers from across the country.

Shoulder and lower back problems have already been highlighted as common issues.

"At least 50 per cent of the time in the water is spent paddling. The position this puts your body in is quite unnatural with your head extended forward."

An avid surfer herself, Remnant knows the torture surfers go through when injury hits.

Shoulder injuries and 12 stitches to the head have kept her high and dry for too long.

"Every surfer I speak to has an injury story or one they are dealing with at the time. The problem is a lot of these people are really young."

"You need to get your fix and if you're injured that desire to get out there is 10 times worse."

Surfers can visit surfinginjury.co.nz to complete the survey.

http://www.stuff.co.nz/national/education/77842403/unitec-research-project-exposing-surfing-injuries
Appendix I

Advert with link to ‘Surfing Injuries NZ’ questionnaire on the Swellmap surf report website from January 2016 until May 2016. (http://www.swellmap.co.nz)
Appendix J

Examples of Facebook pages that survey was promoted with link to questionnaire.
Examples of Facebook posts with link to questionnaire.

---

29 December 2015

To every SURFER who is currently in New Zealand!
I would really appreciate your support with my national surfing survey that I am conducting as part of my Osteopath Masters thesis. The aim is to capture a snap shot of New Zealand surfing and related injuries, however you do not need to be injured to complete this survey.
There is an O’Neill 4/3 WETSUIT (Hyperfreak) up for grabs as a prize draw for everyone who completes the survey.
Click below to take the survey and please tag your surfing friends... Thanks heaps!!!
www.surveymonkey.com/r/SURFINGINJURIESNZ

---

17 February 2016

Huge thanks to Jwan Mlek at www.raganphotogallery.com for the photo!
Here's the link to the survey and please share with all your surfer friends in NZ
www.surfinginjury.co.nz ... they can win an O'Neil 4/3 wetsuit ... or just be part of the research that will hopefully help us prevent and reduce surfing injuries... See more

---

Exposing the injuries beneath the waves - National - NZ Herald News
Shining a light on the hidden physical toll of wipe-outs and other surfing injuries is the aim of a first-of-its-kind Kiwi study. - New Zealand Herald
NZHERALD.CO.NZ
Appendix K

A community Facebook page, ‘Surfing Injuries NZ’ was specifically designed for this study and used for promotions of questionnaire.
Appendix L

The wetsuit winner was drawn by a random sequence generator online on May 18, 2016.
The randomly drawn number was matched to the respondent number on SurveyMonkey.
The winner was announced (anonymously) on the ‘Surfing Injuries NZ’ Facebook page on May 23, 2016.

The winner of the O’Neill 4/3 Hyperfreak wetsuit is some lucky guy in Canterbury ... Congrats!

Thanks so much O’Neill for kindly supporting this research 😊

Huge thanks also to my family, friends, Unitec team and everyone in the NZ surfing community, especially www.swellmap.co.nz, that helped spread the word about this research... It’s blown my mind how many people shared these posts and tagged their surfing mates. You’re all awesome and this wouldn’t have happened without you... See more
Full name of author: Debbie Remnant

ORCID number (Optional): 

Full title of thesis/dissertation/research project (‘the work’):
Gradual-Onset Surfing Injuries in New Zealand – A Retrospective Epidemiological Study

Practice Pathway: Osteopathy
Degree: Master of Osteopathy
Year of presentation: 2017

Principal Supervisor: Dr Catherine Bacon
Associate Supervisor: Rob Moran

Permission to make open access
I agree to a digital copy of my final thesis/work being uploaded to the Unitec institutional repository and being made viewable worldwide.

Copyright Rights:
Unless otherwise stated this work is protected by copyright with all rights reserved.
I provide this copy in the expectation that due acknowledgement of its use is made.

AND

Copyright Compliance:
I confirm that I either used no substantial portions of third party copyright material, including charts, diagrams, graphs, photographs or maps in my thesis/work or I have obtained permission for such material to be made accessible worldwide via the Internet.

Signature of author: 

Date: 10 /07/2017