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Assessment of competitive requirements, repeated sprint paddle ability and trainability of paddling performance in surfers

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Assessment of Competitive Requirements, Repeated Sprint Paddle Ability and Trainability of Paddling Performance in Surfers

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Dedication

I dedicate this thesis to all those who have been there as part of this since day one, the middle and the end and to those who are no longer with us to see what we have achieved

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Abstract

Studies examining the physical demands of surfing, the physiological characteristics of surfers, training techniques and various indices important to surfing performance are limited and characterised by methodological discrepancies. This thesis consists of five studies to assess the competitive requirements, test specific repeat sprint fitness and the trainability of sprint paddling in surfers.

Initially an understanding of surfing movement patterns and a determination of the reliability and validity of custom-made GPS units was established (SurfTraX, Gold Coast, Australia) (Study 1: *The validity and inter-unit reliability of custom-made SurfTraX GPS units and use during surfing*). Durations, intensities, external loads and velocity of movements during competitive surfing were then examined (Study 2: *Workloads of competitive surfing: A performance analysis of three surfing competitions*). During competition surfers paddle 44% of the total time and have a significantly higher work to rest ratio at a beach-break compared to point-breaks. Further, point-breaks involve longer continuous durations of paddling, with significantly longer rides, compared to the beach-break. Data from Study 2 aided in forming the rationale for developing and determining the reliability of a novel repeat sprint paddle test (RSPT) (Study 3: *The repeat-sprint paddle test: A protocol for measuring surfing athletes' sprint paddle performance).* With lacking appropriate and valid testing protocols for evaluating physiological qualities in surfing athletes, Study 3 determined that the measurements of RSPT total time, best 15m time, and peak velocity from recreational and competitive surfers were reliable between days. Additionally, the smallest worthwhile change ranged from 0.02 to 2.7 s, demonstrating high sensitivity in detecting performance changes. After determining the reliability of the RSPT, this study investigated the durations that adolescent competitive surfers spend surfing and physically training.

In the pilot study (Study 4: *Tracking 6 Weeks of Training/Surfing Sessions of Adolescent Competitive Surfers: Just what are these young surfers up to?)* adolescent surfers provided details on the amount of time spent free surfing, being coached, competing, strength training, conditioning and undertaking balance work over six weeks. It was found that adolescent surfers spent 14 more hours surfing than doing any form of land-based training, including no form of specific paddle training.

Following the conclusions of Study 4, Study 5 examined the effectiveness of implementing structured training on the paddling abilities of adolescent surfers (Study 5:

Five weeks of sprint and high intensity interval training improves paddling performance in adolescent surfers). It was discovered that high intensity interval training (HIT) (30 s sprint paddling) decreased athletes 400m endurance paddle time, and sprint interval training (SIT) (10 s sprint paddling) decreased the total RSPT time. Such training can be implemented to improve aerobic and repeat sprint paddle ability, which are key aspects of the sport. Additionally, the 400m paddle and RSPT can possibly discriminate between aerobic and anaerobic training adaptations, with aerobic gains likely from HIT and anaerobic gains likely from SIT.

Overall, this thesis established greater in-depth information on competitive surfing, an innovative and reliable test to assess repeat sprint ability, and two training methods that produced beneficial sprint and endurance paddle improvements.

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List of Publications and Presentations Related to Thesis

Original Research

Farley, O. R. L., Secomb, J. L., Raymond, E. R., Lundgren, L., Ferrier, B., Tran, T, T., Abbiss, Chris., Sheppard, J. M. (2016). Workloads of competitive surfing: A performance analysis of three surfing competitions. (Journal of Sports Sciences, In Review)

- 80% own work, performed the experiments and wrote the paper

Farley, O. R. L., Secomb, J. L., Lundgren, L., Ferrier, B., Parsonage, J., Abbiss, C., Sheppard, J. M. (2016). The repeat-sprint paddle test: A protocol for measuring surfing athletes' sprint paddle performance. (Strength and Conditioning Journal, In Review)

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- 80% own work, investigated literature and wrote the paper

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- 80% own work, investigated literature and wrote the paper

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Just what are these young surfers up to? *Journal of Australian Strength and Conditioning*, 23(6), 98-100.

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- 80% own work, performed the experiments and wrote the paper

List of Co-author Publications arising from PhD

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Secomb, J. L., Nimphius, S., **Farley, O. R. L**., Lundgren, L. E., Tran, T. T., & Sheppard, J. M. (2015). Relationships between lower-body muscle structure and, lower-body strength, explosiveness and eccentric leg stiffness in adolescent athletes. *Journal of Sports Science & Medicine*, *14*(4), 691.

- 4% contribution - aided with the experiments and revisions

Secomb, J. L., Nimphius, S., **Farley, O. R. L**., Lundgren, L., Tran, T. T., & Sheppard, J. M. (2015). Lower-body muscle structure and jump performance of stronger and weaker surfing athletes. *International Journal of Sports Physiology and Performance*.

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Secomb, J. L., **Farley, O. R. L**., Lundgren, L., Tran, T.T., King, A., Nimphius, S., Sheppard, J. M., Meir, R. and Triplett, T. (2015). Associations between the performance of scoring manoeuvres and lower-body strength and power in elite surfers. *International Journal of Sports Science and Coaching*, *10*(5), 911-918.

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Conference Abstracts

Farley, O. R. L., Coyne, J., Secomb, J. L., Lundgren, L., Tran, T. T., Abbiss, C., Sheppard, J. M. Comparison of the 400 metre timed endurance surf paddle between elite competitive surfers, competitive surfers and recreational surfers. Australian Strength and Conditioning Association Conference, Melbourne, VIC, Australia, 2013. Poster Presentation: (Appendix 6).

Farley, O. R. L., Andrews, M., Secomb, J. L., Tran, T. T., Lundgren, L., Abbiss, C., Sheppard, J. M. The validity and inter-unit reliability of custom-made SurfTraX GPS units and use during surfing. Australian Strength and Conditioning Association Conference, Melbourne, VIC, Australia, 2014. Poster Presentation: (Appendix 7).

Farley, O. R. L., Secomb, J. L., Parsonage, J., Lundgren, L., Abbiss, C., Sheppard, J. M. Tracking 6 Weeks of training/surfing sessions of adolescent competitive surfers:
Just what are these young surfers up to? Australian Strength and Conditioning Association Conference, Gold Coast, QLD, Australia, 2015. Poster Presentation: (Appendix 8).

Use of Thesis

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Chapter 1:
Introduction and General Overview

The sport of surfing, referred to as he‘e nalu (he‘e: to ride; nalu: the surf) by Polynesians (Nendel, 2009), is an ancient sport with origins in noble tradition. Chiefs took their rightful place when surfing, riding bigger boards and challenging bigger waves than that of commoners, who would ride smaller boards away from the chiefs (Harvey, 2009). Documentation of the sport is scarce prior to Captain James Cook’s observations of Tahitian canoe surfing in 1777; however, surfing in the form as many would identify with today, was invented and mastered by Hawaii’s population around 1000 years ago, with both royalty and commoners participating (Warshaw, 2003).

At the turn of the twentieth century Hawaii was annexed by the United States of America. As a result, the once cultural and religious pastime of surfing became increasingly commercialised, losing its noble traditions and becoming comparative with other American sports such as baseball, football and basketball (Nendel, 2009). The transformation of surfing saw three-time world record holder and multiple Olympic gold medal champion in freestyle swimming, Duke Paoa Kahanamoku, embark on a world tour in 1915, where he provided a major stimulus in the development of surfing in Sydney, Australia (Osmond, 2011). Since this time, surfing has continued to grow in popularity to become a thriving culture (Mendez-Villanueva & Bishop, 2005). Surfing has undergone multiple changes, not only with advances in equipment (i.e. surfboard design and construction, wetsuits and surf apparel), but also in the way surfers are riding the waves. Modern day surfing contains aggressive quick turns and airborne innovative manoeuvres incorporating gymnastic type movements which are now commonplace within surfing (Lundgren, Tran, Dunn, Nimphius, & Sheppard, 2014; Souza, Rocha, & Nascimento, 2012).

Surfing requires athletes to paddle in a prone position for a prolonged duration. The surfer must also be capable of navigating through or around breaking waves, against currents, moving to different locations and remaining stationary while recovering or waiting for a suitable wave (Farley, Harris, & Kilding, 2012a; Lowdon, 1983). Powerful paddling is required when trying to ‘catch’ a wave, thus ensuring enough momentum has been generated to enter the wave with adequate entry speed before quickly ‘popping-up’ (prone to standing) on the board. Once up on the board and riding, the surfer requires balance, strength, power, coordination, mobility of body joints and the ability to react to critical situations during wave riding, such as anticipating and adapting to the continuously changing wave formation (Lowdon, 1983; Lowdon & Pateman, 1980; Mendez-Villanueva & Bishop, 2005). The combination of the aforementioned physiological aspects are vital in performing the turns, snaps, cutbacks on the wave face, launching into the air for aerials manoeuvers and landing safely, while remaining in control on the board (Everline, 2007; Tran, 2015). From a competitive aspect, judges score performance during wave riding in reference to several key criteria, which are based on the surfer’s ability to successfully perform difficult manoeuvres with commitment and in combination (ASP, 2013; Farley, Raymond, et al., 2015).

The first surfing world championship was held in Sydney, Australia, in 1964 (Kampion, 2003), however, formal training for such events was not a prerequisite. During the 1970s and 1980s the majority of competitors had no specific or suitable training routine, with the common belief that surfing alone was sufficient for developing the physical fitness required for competition (Lowdon, Mourad, & Warne, 1990). Over the last two decades the sport has grown substantially with an increase in the attention given to the physical preparation of elite surfers (Farley et al., 2012a; Mendez-Villanueva & Bishop, 2005; Mendez-Villanueva et al., 2005; Secomb, 2012; Sheppard et al., 2012; Sheppard et al., 2013). Converse to the growth of competitive surfing, limited research is available which examines the physical demands of the sport (Barlow, Gresty, Findlay, Cooke, & Davidson, 2014; Farley, Harris, & Kilding, 2012b; Meir, Lowdon, & Davie, 1991; Mendez-Villanueva et al., 2005; Secomb, Sheppard, & Dascombe, 2014). Previous researchers have noted that environmental factors involved in surfing influence the physical and energy demands of the sport (Lowdon, Bedi, & Horvath, 1989; Lowdon & Lowdon, 1988; Meir et al., 1991). Indeed, competitions take place under a variety of conditions that can be affected by the weather, swell, tides and the type of break/wave, all of which ultimately affect physiological demands imposed onto the surfers (Barlow, Gresty, et al., 2014; Farley et al., 2012b; Meir et al., 1991; Mendez-Villanueva et al., 2005; Secomb et al., 2014). However, methods to best physically prepare such athletes is currently unclear, with no literature to date reporting on specific water training methods. Recently training has focused on strength, power and utilisation of stable and unstable (i.e. BOSU balls) methods (Everline, 2007; Tran et al., 2015).

Surfing is a unique sport in which participants do not pay conscious attention to training but instead practice when they have time and the surf conditions will permit (Lowdon et al., 1989). It has been previously documented that surfers can spend between 3.7 to 5 hours a day practicing in good surf conditions, three to five days a week for recreational and international level surfers (Lowdon, Pateman, & Pitman, 1983; Lowdon, Pitman, Pateman, & Ross, 1987; Mendez-Villanueva & Bishop, 2005). Within juniors (<19 y), weekly surfing hours range between 7.5 (Recreational surfers) to 18 (Competitive surfers) hours surfing each week (Loveless & Minahan, 2010a). Interestingly, the amount of time elite surfers spend in the water is similar to the training times of elite athletes in other sports, yet surfers are more likely to consider this time as recreational rather than as training (Lowdon et al., 1989).

During competition professional and elite surfers can compete in up to three heats per day, lasting between 20 to 40 minutes each, during which approximately 50% of the total time is spent paddling (Farley et al., 2012b; Meir et al., 1991; Mendez-Villanueva, Bishop, & Hamer, 2006). Studies have reported that competitive surfing is characterised by repeat high-intensity intermittent bouts of paddling (60% performed between 1 – 10 s), with short periods of recovery (64% between 1 – 10 s), resulting in moderate (140 $b{\cdot}min^{-1}$) to high (190 $b{\cdot}min^{-1}$) heart rates and a total distance of approximately 1km travelled in each 20 minute heat (Farley et al., 2012b; Meir et al., 1991; Mendez-Villanueva & Bishop, 2005). Due to these physical demands it has been suggested that surfers are required to have a high muscular endurance, anaerobic power of the upper torso, excellent cardio-respiratory fitness and be able to rapidly recover from brief high-intensity efforts (Lowdon, 1983; Lowdon et al., 1989). However, with such requirements for the sport it is surprising these athletes do not partake in extra conditioning to enhance these qualities.

Given the high metabolic demands of surfing, literature on surfer's aerobic and anaerobic characteristics is surprisingly limited. Technological developments in laboratory-based ergometers has seen such devices being utilised as an alternative to swimming pool-based testing in the assessment of arm power, anaerobic and aerobic fitness (Farley et al., 2012a; Kimura, Yeater, & Martin, 1990; Loveless & Minahan, 2010a, 2010b; Lowdon et al., 1989; Meir et al., 1991; Mendez-Villanueva et al., 2005; Morton & Gastin, 1997). Previous studies have used tethered board paddling (Lowdon et al., 1989), arm cranking (Lowdon et al., 1989), swim-bench ergometers (Loveless & Minahan, 2010a, 2010b; Meir et al., 1991) and modified kayak ergometers (Farley et al., 2012a; Mendez-Villanueva et al., 2005) to investigate peak or maximal aerobic capacity (VO_{2peak} or VO_{2max}) and anaerobic power during surfboard paddling. These studies have indicated that the aerobic capacity of surfers are comparable to other sports involving upper-body paddling, such as swimming (50 – 70 $mL \cdot kg^{-1} \cdot min^{-1}$) (Kimura et al., 1990) and surf-life saving (40 $mL \cdot kg^{-1} \cdot min^{-1}$) (Morton & Gastin, 1997). However, the importance of cardiovascular fitness to surfing performance is not entirely clear. Indeed, from many of the previous studies on surfers, there has been no significant correlation identified between the surfer's season ranking and relative VO_{2peak} (Farley et al., 2012a; 2010a; Lowdon et al., 1989; 1991; Mendez-Villanueva et al., 2005). While VO_{2peak} does not appear to be a discriminator of surfing performance, it is just one aspect of cardiovascular fitness.

Given the significant amount of time surfers spend paddling at low to moderate intensities, cardiovascular fitness is likely to be an important aspect of the sport. Additionally, with the prominence of the short bursts of paddling (1 – 10 s) to catch a wave it is not surprising that significant relationships between surfers' season rank and anaerobic peak power output have previously been reported (Farley et al., 2012a). Much of this work examining aerobic and anaerobic capacity in surfers has been obtained in laboratory settings using ergometer activities (i.e. tethered board paddling, arm cranking, swim-bench ergometers and modified kayak ergometers) (Farley et al., 2012a; Kimura et al., 1990; Loveless & Minahan, 2010a, 2010b; Lowdon et al., 1989; Meir et al., 1991; Mendez-Villanueva et al., 2005; Morton & Gastin, 1997), which may have limited validity. Indeed, the relationship between power output measured on an ergometer and the power generated when paddling on-water during surfing is currently unclear (Farley et al., 2012a; Loveless & Minahan, 2010a). Pool-based testing would seem more appropriate given the nature of the sport; therefore, the development of reliable and valid on-water assessments for anaerobic and aerobic performance of surfers is worthwhile. Currently however, surfing specific pool testing for surfers is limited and typically comprises of only a 15m sprint paddle and 400m endurance paddle (Sheppard et al., 2012). Therefore, further testing methodologies to determine the physiological aspects of paddling performances need to be developed.

With the importance of repeated short bursts of paddling (1 – 10 s) to catch a wave, aerobic and anaerobic characteristics (Farley et al., 2012a; Loveless & Minahan, 2010a, 2010b; Lowdon & Pateman, 1980; Meir et al., 1991; Mendez-Villanueva et al., 2005) and the significant relationships between surfers' season rank and anaerobic peak power output (Farley et al., 2012a), training to enhance these qualities should be investigated. The physical capacity to catch waves and out-paddle opposition during a heat is a vital component of the sport and could be the difference between winning and losing. Surfers with superior sprint paddling ability may have an advantage against their competition in a heat by sitting deeper on the peak of the wave, thereby controlling the line-up (Tran, 2015). Therefore, training methods should emphasise these energy systems, particularly anaerobic sprint power given the importance for wave entry speed (Sheppard et al., 2012). Training methods for improving athletic performance such as high intensity interval training and sprint interval training may help surfers with aerobic conditioning, repeated efforts and anaerobic repeat sprint paddle ability. Training methods that have emerged as highly effective with improving aerobic performance and metabolic functioning are high intensity interval training (HIT) and more recently sprint interval training (SIT) (Billat, 2001; Buchheit & Laursen, 2013a, 2013b; Laursen & Jenkins, 2002). From a surfing specific stand point, HIT has potential to be a favourable training stimulus for VO_{2max} enhancements (Buchheit & Laursen, 2013a; Buchheit et al., 2008; Gibala, 2009; Gibala & McGee, 2008) and SIT for improving sprint paddle power and repeat sprint paddling ability (Burgomaster et al., 2008; Gibala et al., 2006; Gibala & McGee, 2008). Such adaptations would be highly beneficial for competitive athletes to withstand the demands of surfing and gain an upper edge over fellow competitors.

1.2 Research Purpose

The main objective of this thesis was to better understand the physiological factors important to surfing performance. In order to create an informed training prescription for the preparation of elite surfers, the reliability and validly of the SurfTraX GPS units (Study 1) was determined. The activity profile and exercise durations of competitive surfing competitions were then quantified using performance analysis methods (Study 2). The results from Study 2 assisted in the design, validity and reliability of a repeated sprint paddle test (RSPT) that reflects the demands of the sport (Study 3). Thereafter, the thesis examined the training loads of adolescent competitive surfers (Study 4) and the effectiveness of implementing structured training programmes in surfing athletes. Specifically, the results of Study 2 aided in the design of two distinct training methods aimed at improving aerobic and anaerobic capacity of surfing athletes (Study 5).

1.3 Research Significance

The growth of competitive surfing and increased attention given to these athletes striving to qualify and compete at the highest level of international surfing requires coaches and athletes alike to be up to date with the latest scientific literature to help enhance the qualities required to win. Research on the competitive requirements, physiological demands, assessment of fitness and trainability of anaerobic and aerobic fitness qualities of surfers is vital for the growth of elite surfing performance. Such information will support the development of surf specific on-and-off-water training programmes. The findings from this thesis provide additional surfing literature, thus informing sports scientists, coaches and the wider surfing community on methods to improve surfing performance. The use of the data from this thesis will also provide an in-depth analysis of competitive surfing and physical requirements at different locations/breaks; a test for measuring surfers' repeat sprint paddle ability, which can be used for performance monitoring; applicable water based paddle-training methods that improve paddle performance and talent identification through the aforementioned information.

1.4 Research Questions and Hypothesis

Study 1

1. Are the SurfTraX GPS units capable of measuring the actual measured distance correctly between day-to-day tests and between units during 100m of sprinting, rugby field walking and a 'W' shape run?
    - *Measured distances will not be the same between day-to-day testing and between units. GPS units will not measure the actual distances correctly. The GPS units will underestimate the actual distance at sprinting 100m and running in a 'W' shape but will be accurate during the walk.*
2. What is the day-to-day and between unit reliability of SurfTraX GPS units during 100m sprinting, rugby field walk and a 'W' shape run?
    - *The day-to-day results within all tests will provide similar results, but will have a small error for all speeds and distance measures. All GPS units will provide reliable inter unit data during the walk, but will not be as reliable during the 100m sprint or the W running course, again subject to small errors within measures.*

Study 2

1. What are the activity profiles (i.e. exercise durations, distances, velocity of movements, work to rest ratios) experienced during competitive surfing and do these demands differ between surf break locations/type?
    - *Competitive surfing will be characterised by short duration (4-6s) moderate- to high-intensity bouts of paddling, cover approximately 1km per 20 minutes of surfing time. Overall intensity (velocity), the percentage of time spent paddling and the percentage of time spent wave riding will differ between locations. The total distance travelled and overall time spent wave riding will be higher at a point-break compared to a beach-break.*
2. Do the activity profiles differ between surfers competing in the same heats and are higher ranked surfers surfing faster, further and catching more waves?
    - *The distances travelled, number of waves caught, sprint paddles and rest periods will be different between surfers of all levels. Therefore, the activity profiles will differ. Higher ranked surfers will paddle further, catch more waves and generate more speed on a wave.*

Study 3

1. Are measurements of total time, fastest time, fatigue index, peak velocity and blood lactate assessed using the repeat sprint paddle test reliable between day-to-day trials?
    - *The test will be reliable between days, providing a reliable measure of performance and blood lactate.*
2. Does a pool-based repeat sprint paddle test provide discriminatory validity data between surfers of varying abilities and paddling performance?
    - *Performance measure outcomes from the RSPT will be greater for higher ranked surfers, compared with lower ranked surfers and that of recreational surfers.*

Study 4

1. How many hours a week do adolescent surfers spend in the water surfing in terms of free surfing, being coached and competing?
    - *Surfers will spend around 12 hours of free surfing per week, 4 hours being coached and 20 minutes competing.*

2. How many hours a week do adolescent surfers spend physically training as part of a structured weekly plan performing strength, balance and conditioning work?
    - *Surfers will not spend any time strength training, but will spend 4 hours conditioning and 2 hours' balance training per week.*

Study 5

1. Does additional, specific paddle based training of high intensity interval training (HIT), or sprint interval training (SIT) improve surfing performance (aerobic conditioning, repeated efforts and anaerobic repeat sprint paddle ability)?
    - *SIT will produce significant improvements in the 15m sprint paddle but not the 400m paddle. HIT training will improve anaerobic threshold and result in improvements in the 400m paddle and the repeat sprint paddle test.*

1.5 *General Overview*

In spite of the recent growth in the professionalism of surfing there is still a paucity of research into surfing performance as a whole. While there has been an attempt to identify the physical demands of surfing through performance analysis, relationships between indices of surfing performance and physiological demands and/or characteristics of surfers, current research is characterised by methodological discrepancies. Currently there is no in-depth performance analysis of competitive surfing nor is there any investigation between locations and individual competitors. Specific pool-based paddling testing protocols to assess surfing athletes' repeat sprint paddle performance or studies investigating the implementation of interval paddling, are also not evident in current research.

As such, this thesis consists of five studies to assess the competitive requirements, test specific repeat sprint fitness and the trainability of sprint paddling in surfers. The purpose of this thesis was to firstly determine the reliability and validity of custom-made GPS units for use in surfing (Study 1), thereafter investigate the durations, intensity, external loads and velocity of movement during competitive surfing (Study 2). During Study 2, participants wore a GPS tracking unit while simultaneously being filmed for synchronisation and time-motion analysis at three different surfing locations and events.

The performance analysis aided in forming a basis of rationale for developing and determining reliability of a novel repeat sprint paddle test (RSPT) (Study 3). Additionally, performance measurements recorded from RSPT were used to determine if blood lactate, total time, peak velocity, fastest 15m time and fatigue index are relevant for surfing performance and whether the RSPT provides additional discriminatory information beyond an existing test (i.e. 400m endurance time trial).

The pilot study (study 4) questioned eight adolescent surfers twice a week for six weeks during which they reported on the weekly surfing hours and structured training hours they undertook. Several participants did not report any form of structured training. Given that such structured training has been reported on to improve performance in many sports, these findings warrant the need for investigation into the benefits of structured training within surfing. Thereafter, the fifth study (Study 5) examined the effects of two specific training methods; sprint interval training (SIT; 10 s paddle bursts) and high intensity interval training (HIT; 30 s paddle bursts). Such training methods were implemented to improve 400m time trial and anaerobic repeat sprint paddle ability in adolescent surfers. Overall, this thesis contributed to the establishment of reliable GPS units for use in surfing research, work to rest ratios at different types of surf breaks and the competitive demands on a greater scale. Further, it determined specific performance testing protocols for competitive and recreational surfing athletes, the surfing and structured training hours of competitive adolescent surfers and the implications of HIT and SIT in improving aerobic and repeat sprint paddle ability.

Chapter 2: Literature Review Performance Analysis of Surfing

Due to Copyright reasons,

Chapter 2 is unavailable in this version of the thesis.

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Chapter 3: Literature Review Testing Protocols for Profiling of Surfers' Anaerobic and Aerobic Fitness

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Chapter 4: Literature Review
The Utilisation of Sprint and High-Intensity Interval Training to aid in Surfers' Trainability for such Prerequisites

4.1 Introduction

Competitive surfing is a sport that is predominantly characterised by intermittent paddling bouts that vary in intensity and duration (Farley et al., 2012b; Mendez-Villanueva et al., 2006; Secomb et al., 2014). This is due to surfing involving prolonged periods of paddling to the waves, against currents, moving to different locations and remaining stationary while recovering or waiting for a suitable wave (Farley et al., 2012a; Lowdon, 1983). Not only are professional surfers battling the environmental variables, but they can compete in up to four, 20 to 40 min heats within a single day (Farley et al., 2012b; Meir et al., 1991; Mendez-Villanueva et al., 2006; Secomb, 2012) and can paddle approximately 1km during a 20 min competitive heat (Farley et al., 2012b).

Competitive surfing takes place under a variety of surf conditions, environmental factors and at different surf break locations. As a result, the multiple facets involved ultimately influence the physiological demands encountered (Farley et al., 2012b; Lowdon, 1983; Meir et al., 1991; Mendez-Villanueva et al., 2006; Secomb, 2012). These demands are further increased by intermittent breath holding during the duck-diving process under advancing broken waves and during wave hold-downs (Loveless & Minahan, 2010a, 2010b; Lowdon, 1983; Lowdon et al., 1989; Lowdon & Pateman, 1980; Meir et al., 1991; Mendez-Villanueva & Bishop, 2005; Mendez-Villanueva et al., 2006; Mendez-Villanueva et al., 2005). This is illustrated by the fact that surfers typically paddle between 60% (Mendez-Villanueva et al., 2006) and 80% (Farley et al., 2012b; Secomb et al., 2014) of the total paddling time between 1 and 20 s. From these paddling bouts, it has been reported that approximately 60% (Farley et al., 2012b; Secomb et al., 2014) of the total time paddling is spent paddling between 1 and 10 s, interspersed with short periods of recovery (64% between 1 – 10 s), resulting in moderate (140 $b \cdot min^{-1}$) to high (190 $b \cdot min^{-1}$) HR (Farley et al., 2012b; Mendez-Villanueva et al., 2006; Secomb, 2012).

In addition to the prolonged periods of submaximal exercise, surfers are also required to perform short powerful bursts of paddling (4 – 5 s) to reposition in the surf and to gain crucial enough momentum for the wave take-off (Farley et al., 2012a, 2012b; Loveless & Minahan, 2010b; Lowdon, 1983; Lowdon et al., 1989; Lowdon et al., 1990; Lowdon & Pateman, 1980; Meir et al., 1991; Mendez-Villanueva & Bishop, 2005; Mendez-Villanueva et al., 2006; Secomb, 2012; Secomb et al., 2014). These repeated high-intensity bursts of intermittent paddling and short recovery periods emphasise the importance of paddling and recovery ability. This highlights the importance of athletes requiring high muscular endurance; moderate-high cardio-respiratory endurance and recovery, and anaerobic power of the upper-body (Farley et al., 2012a; Lowdon, 1983; Lowdon et al., 1989; Lowdon & Pateman, 1980; Meir et al., 1991; Mendez-Villanueva & Bishop, 2005). Competitive surf athletes also perform high volumes of training/continuous paddling due to the amount of time spent surfing daily/weekly (Loveless & Minahan, 2010a). Therefore, to gain maximal sprint paddle benefits, but limit extra loading onto the shoulders and surrounding muscle groups, a practical, time-efficient training module is required.

The physical capacity to catch waves and out-paddle competitors during a heat is a vital component of the sport and potentially the difference between winning and losing a competitive heat. Surfers with superior sprint paddling ability may have an advantage against their competition in a heat by sitting deeper on the peak of the wave, thereby controlling the line-up (Tran, 2015). Those who are able to out paddle opponents have a greater chance in obtaining ‘priority’. Within competitive surfing, such as on the World Surfing League, the surfer with priority has the unconditional right of way to catch any wave they choose, with priority lost once they catch a wave and/or a surfer paddles for but misses a wave (WSL, 2015). A significant relationship between a surfer’s season rank and anaerobic peak power output has been reported, thus highlighting the importance of anaerobic power as a key aspect for success in the sport (Farley et al., 2012a). Surfers lacking upper-body paddling power to catch the wave will likely hinder their scoring chances due to not being able to enter the wave with speed and commit to ‘catch’ waves at a crucial take-off point (higher risk to fall from having to stand up quickly); commitment is part of the judging criteria (ASP, 2013). Therefore, with a higher entry speed the surfer can generate board speed quickly, thus allowing them to execute the first manoeuvres in the most critical section of the wave with greater speed and power to maximise scoring potential (Sheppard et al., 2012).

From a physiological standpoint, training the aerobic energy system is important due to the continuous submaximal paddling and repeated high-intensity efforts (Farley et al., 2012a;

Loveless & Minahan, 2010a; Lowdon, 1983; Lowdon & Pateman, 1980). Furthermore, key physiological performance aspects of professional surfing athletes include the ability to recovery quickly, withstand the surf break conditions, as well as surf waves with speed, power and execute manoeuvres with flair. Given the importance of sprint paddling performance in surfing, training methods are needed to specifically target the energy systems utilised during such short and powerful movements. Incorporating these aspects in the training regimes of elite surfers may allow sport scientists and strength and conditioning coaches to better prepare these athletes for competition.

Greater analysis of the sport from recent research has allowed an understanding of the physiological demands and workloads associated with surfing. Training in regards to the aforementioned energy systems and performance aspects associated with the sport should be investigated to aid these athletes. Currently however, there is limited literature on training aspects, particularly related to paddling performance and energy systems, which is unlike that of mainstream sports. To date, no studies have specifically reported on the trainability of paddling performance. The development of best practice for training energy systems would aid in the development and preparation of professional surfers. Therefore, this review covers literature investigating various training protocols utilised in sports to enhance the anaerobic and aerobic fitness of athletes. An ever increasing amount of literature has emerged investigating high intensity interval training (HIT) and more recently sprint interval training (SIT), as highly effective methods of training to improve aerobic performance and metabolic functioning (Billat, 2001; Buchheit & Laursen, 2013a; Laursen & Jenkins, 2002). With literature suggesting that surfing athletes need to have repeat sprint paddle ability, upper-body paddling power and a well-developed aerobic capacity, training methods should emphasise these energy systems. For that reason, this review will cover literature based on HIT and SIT in regards to how these methods can be applied to training programmes for surfers.

4.2 High Intensity Interval Training

HIT has emerged as an effective training method for improving both aerobic and anaerobic capacities, with such adaptations dependent on the intensity and duration of work and relief periods, exercise modality and the number of repetitions and sets (Buchheit & Laursen, 2013a, 2013b; Laursen & Jenkins, 2002; Sloth, Sloth, Overgaard, & Dalgas, 2013).

The manipulation of any of these aforementioned variables can affect the acute physiological responses from HIT (Buchheit & Laursen, 2013a). In contrast to submaximal exercise training, which is characterised by prolonged, continuous activity, HIT is normally achieved through the use of intervals with modalities generated from the demands of the sport. Traditional HIT is characterised by intermittent work periods of 30 s interspersed with 30 s of rest, performed at a higher-intensity that is greater than the anaerobic threshold (Laursen & Jenkins, 2002) and that elicits VO_{2max} (Buchheit & Laursen, 2013a, 2013b; Buchheit et al., 2008; Gibala, 2009; Gibala & McGee, 2008). In addition, HIT can be defined as repeated short (≤45 s) to long (2 – 4 min) bouts of high-intensity exercise interspersed with recovery periods (Billat, 2001; Buchheit & Laursen, 2013b; Laursen & Jenkins, 2002) of low-intensity work or inactivity that allow a partial, but often not a full recovery (Laursen & Jenkins, 2002). This type of training repeatedly stresses the metabolic systems used during specific endurance-type exercises (Daniels & Scardina, 1984) at a higher intensity to what is actually required during the activity (Laursen & Jenkins, 2002).

As a result of high volume training, athletes with a greater training age characteristically have a high aerobic capacity, lactate threshold and economy of motion (Jones & Carter, 2000; Laursen & Rhodes, 2001). Therefore, HIT may provide a unique stimulant to further enhance these characteristics (Laursen & Jenkins, 2002; Londeree, 1997). Exercising at intensities close to the athletes' VO_{2max} allows for the recruitment of large motor units (i.e. Type IIA (intermediate) muscle fibres) (Altenburg, Degens, van Mechelen, Sargeant, & de Haan, 2007; Gollnick, Piehl, & Saltin, 1974; Haff & Triplett, 2015; Karp, 2001) and the implementation of near-to-maximal cardiac output, which, sequentially results in oxidative muscle fibre adaptation and myocardium enlargement (Buchheit & Laursen, 2013a). As such, effective stimulus and adaptations require athletes to spend several minutes per HIT session at intensities greater than 90% of VO_{2max} (Billat, 2001; Buchheit & Laursen, 2013a; Laursen & Jenkins, 2002; Midgley, McNaughton, & Wilkinson, 2006). The implications of HIT have been suggested to stimulate the skeletal muscle modelling, typically associated with traditional endurance training (Gibala & McGee, 2008) and increase cardiovascular parameters such as heart size, blood flow capacity and artery dispensability (Krustrup, Hellsten, & Bangsbo, 2004; Rakobowchuk et al., 2008). Indeed, several studies have documented enhanced cardiovascular fitness (Buchheit & Laursen, 2013a; Buchheit et al., 2008; Gibala, 2009; Gibala & McGee, 2008) and VO_{2max} following two (Hazell, MacPherson, Gravelle, & Lemon, 2010; Rodas, Ventura, Cadefau, Cussó, & Parra, 2000) to ten (Hickson, Bomze, & Holloszy, 1977) weeks of structured HIT. Furthermore, it has been reported that an increase in VO_{2peak} and maximal activity of mitochondrial enzymes in skeletal muscle (Laursen & Jenkins, 2002; Ross & Leveritt, 2001) have occurred following six weeks of HIT. Such adaptations in VO_{2max} may be associated with improvements in both oxygen delivery and oxygen utilisation, suggesting that HIT is an extremely effective method of training to improve cardiovascular fitness in athletes (Buchheit & Laursen, 2013a; Buchheit et al., 2008; Gibala, 2009; Gibala & McGee, 2008). By improving cardiovascular parameters a greater amount of energy can be supplied aerobically, thus allowing athletes to sustain intense exercise for longer durations and also recover more rapidly between high-intensity phases (Fernandez-Fernandez, Zimek, Wiewelhove, & Ferrauti, 2012; Hazell et al., 2010; Iaia, Rampinini, & Bangsbo, 2009). It should be noted that such adaptations have been reported from running and cycling studies, however, it has been documented that four weeks of HIT improved aerobic endurance capacity in swimmers (Faude et al., 2008) which is highly applicable to surf athletes.

In many forms, HIT can elicit significant improvements in endurance performance with already highly trained athletes (Laursen, Blanchard, & Jenkins, 2002; Smith, McNaughton, & Marshall, 1999; Stepto, Hawley, Dennis, & Hopkins, 1999). Such performance improvements have been shown to be parallel to the enhancements in ventilator threshold and peak power, but generally not VO_{2max} or economy of motion (Laursen & Jenkins, 2002). For highly trained surfers who typically have a well-developed aerobic capacity (Farley et al., 2012a; Lowdon, 1983; Lowdon et al., 1989; Lowdon & Pateman, 1980; Meir et al., 1991; Mendez-Villanueva & Bishop, 2005), endurance performance, peak power and ventilator threshold enhancement would be beneficial for sprint paddling power and the intermittent repeat sprint paddling seen in the sport. Such improvements from a relatively low impact and time-efficient form of training is positive to implement with surf athletes.

4.3 Sprint Interval Training

SIT is an aspect of HIT involving repeated bouts of maximal intensity work at shorter intervals (10 – 30 s), with relatively long periods of rest (i.e. 4 – 6 repeated ‘‘all-out’’ 30 s efforts separated by 4 min recovery). The implementation of 30 s SIT has been proposed as an innovative and time-efficient method to induce rapid changes in exercise capacity and skeletal muscle energy metabolism (Burgomaster et al., 2008; Gibala et al., 2006; Gibala & McGee, 2008). Like HIT, the magnitude of such performance changes depend on the nature of the training protocol, such as the frequency, intensity, duration and recovery between bouts (Burgomaster, Hughes, Heigenhauser, Bradwell, & Gibala, 2005), with repeated bouts of SIT likely stressing many of the physiological/biochemical systems used in aerobic efforts (Daniels & Scardina, 1984; Laursen & Jenkins, 2002). The small duration of very intense work has been reported to "double" the length of time intense aerobic exercise could be maintained (i.e. from 26 to 51 min) (Coyle, 2005) and has been further documented to improve cardiovascular fitness and peripheral muscular adaptations (Burgomaster et al., 2008; Gibala et al., 2006; Gibala & McGee, 2008; Sloth et al., 2013). The metabolic changes reported are likely a result of the high simultaneous stress on both the anaerobic and aerobic energy systems.

The effectiveness of SIT is associated with to the high level of motor unit activation as mentioned in HIT. All-out sprint training stresses the recruitment and adaptation of Type IIA (intermediate) muscle fibres that are just as responsive as Type I (slow twitch) muscle fibres in increasing mitochondrial enzyme activity to high absolute levels (Chi et al., 1983; Coyle, 2005; Dudley, Abraham, & Terjung, 1982; Haff & Triplett, 2015; Jansson & Kaijser, 1977). As such, the implications of SIT have been reported to increase mean and peak anaerobic capacity (Barnett et al., 2004; Burgomaster et al., 2007; Burgomaster et al., 2008; Burgomaster et al., 2005; Hazell et al., 2010; McKenna et al., 1997) and maximum short-term power output (MacDougall et al., 1998). Furthermore, alterations in glycolytic enzymes, increase muscle Cr and CK levels (Burgomaster et al., 2008), muscle buffering and ionic regulation following SIT result in improved anaerobic performance (Burgomaster, Heigenhauser, & Gibala, 2006; Burgomaster et al., 2005; Gibala et al., 2006; Harmer et al., 2000; Hazell et al., 2010; MacDougall et al., 1998). The increased maximal glycolytic enzyme activity and sodium potassium (Na+-K+) pump capacity are also suggested to improve power output (MacDougall et al., 1998). Given the utilisation of aerobic metabolism during repeated sprinting (Bogdanis et al., 1996b; McKenna et al., 1997), increases in muscle oxidative capacity have been reported (Burgomaster et al., 2008; Gibala et al., 2006) after 6 to 8 weeks of SIT (Burgomaster et al., 2005; Jacobs, Esbjörnsson, Sylven, Holm, & Jansson, 1987; MacDougall et al., 1998).

Of particular interest to the implementation of power burst paddling in surfing, especially when paddling into a wave, is that individual SIT bouts are typically characterised by the generation of peak power output within the first 5 to 10 s. For an athlete preforming traditional 30 s bursts, the power output declines for the remaining 20 to 25 s, however, maintenance of a high power output is required (Hazell et al., 2010). One study (Hazell et al., 2010) demonstrated that modified SIT protocols (4 – 6 x 10 s:2/4 min recovery, three times per week over two weeks) produced similar and significant VO_{2max} and 5km time trial performance improvements when compared with the established 30 s:4 min SIT protocol. Such performance improvements were attributed to the generation of peak power output and higher intensity of work during the first few seconds of each training bout compared to 30 s SIT (Hazell et al., 2010). However, the underlying mechanism responsible for these rapid adaptations requires further investigation. Nonetheless, such adaptations are highly relevant to surfers' sprint paddles, with the main stimulus of SIT being the generation of peak power output (Hazell et al., 2010).

4.4 Repeated Ability

During surfing, there are periods where the athlete performs multiple repeated efforts and short sprint bursts of paddling, such as when duck diving under waves and paddling quickly before repeating the same process, or when repositioning for a wave after missing one, then paddling quickly for another wave. The ability to repeat, short bursts of sprints/efforts (1 – 7 s), with brief recovery periods (≤30 s), is asserted to be a critical aspect of athletic fitness and sprint ability within field and court-based team sports (Newman, Tarpenning, & Marino, 2004; Turner & Stewart, 2013; Wadley & Le Rossignol, 1998). This repeated sprinting, termed repeated sprint ability (RSA) (typically attributed to ≤10% of total activity and defined by a number of sprints and rest in a specified time period) has been established as an important fitness component and critical in the outcome of a field-based match (Oliver, Williams, & Armstrong, 2006; Reilly, 1997). Athletes who are able to produce and maintain a higher RSA are likely to outperform and withstand a higher physiological workload than athletes with a lower ability (Bishop, Spencer, Duffield, & Lawrence, 2001).

Literature has recently moved away from RSA and begun referring to it as repeat effort ability (REA). In a rugby league study, athletes performed a repeated-sprint (12 x 20m sprints performed on a 20 s cycle) and a repeated-effort (12 x 20m sprints with intermittent tackling, performed on a 20 s cycle) (Johnston & Gabbett, 2011). The authors suggested that the addition of tackling significantly increased the physiological response to repeated-sprint exercise and reduced repeated-sprint performance in rugby league players (Johnston & Gabbett, 2011). This method of training and testing could be applied to surfing when aspects such as duck diving are included in the definition because it then encompasses all activities that are energetically demanding. Therefore, given that competitive surfers are engaged in such paddling bouts, including the other multiple facets that are energetically demanding, it is likely that a greater repeat sprint ability or repeated effort could also be beneficial to surfing athletes as seen in team based sports (Johnston & Gabbett, 2011; Sheppard et al., 2007).

4.5 Utilisation of Training Methods

Given that typical paddling bouts range between 1 and 20 s, accounting for between 60 and 80% (Farley et al., 2012b; Mendez-Villanueva et al., 2006; Secomb et al., 2014) of the total paddling time (with approximately 60% (Farley et al., 2012b; Secomb et al., 2014) of the total time spent between 1 and 10 s paddling), training methods should specifically target the energy systems utilised during such short and powerful movements. Additionally, due to the high volumes of training/surfing, daily/weekly (Loveless & Minahan, 2010a) and demands of the sport, a practical, time efficient protocol needs to be established for paddling enhancement. Therefore, particular to the nature of surfing, HIT and SIT would seem viable training choices given the conclusions of current literature (Gibala, 2009; Gibala & McGee, 2008). The addition of RSA and REA could also be applied into training, with modifications of RSE including intermittent high intensity bouts of all out paddling and intermittent breath holds intercalated with relatively short recovery periods (Ref Farley phys demns paper). In addition, a repeat sprint paddle test should be investigated, given the establishment of RSA in team sports a reliable test, such testing protocols have not been developed in surfing.

From literature to date, it appears that exercise intensity is a more critical aspect of aerobic training adaptations rather than exercise volume (Macpherson, Hazell, Olver, Paterson, & Lemon, 2011). Studies using similar methods have reported HIT (90 s burst) induced greater improvements in sport-specific endurance and repeat sprint training, (5 s bursts) which led to a significant improvement in repeat sprint ability (Fernandez-Fernandez et al., 2012). As such, it would appear that HIT and SIT, although very similar in adaptations, also share differences in the recruitment of the metabolic energy systems and concurrent acute physiological responses. From a surfing specific standpoint, HIT has potential to be a favourable training stimulus for VO_{2max} enhancements and SIT for improving sprint paddle power and repeat sprint paddling ability. Such adaptations would be highly beneficial for competitive athletes to withstand the demands of surfing and gain an upper edge over fellow competitors. Benefits include out paddling and gaining priority over fellow competitors and entering the wave from a more critical section with greater speed. This would allow athletes to commit to waves earlier on, thus allowing higher scoring chances and also the execution of manoeuvres in the most critical section of the wave to maximise scoring potential (Sheppard et al., 2012).

Chapter 5: Study 1: The Validity and Inter-Unit Reliability of Custom-Made SurfTraX GPS Units and use during Surfing

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Chapter 6: Study 2: Workloads of Competitive Surfing: A Performance Analysis of Three Surfing Competitions

At the author's request,

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Chapter 7:

Study 3: The Repeat-Sprint Paddle Test: A Protocol for Measuring Surfing Athletes' Sprint Paddle Performance

(Strength and Conditioning Journal, In Review)

7.1 Introduction

Competitive surfing has become increasingly popular over the past few years with a greater interest now being placed on the physical and physiological development of these athletes (Farley et al., 2012a; Mendez-Villanueva & Bishop, 2005; Mendez-Villanueva et al., 2005; Secomb, 2012; Sheppard et al., 2012; Sheppard et al., 2013). Specific testing protocols for assessment of performance and physiological characteristics relevant to surfing are important. Research on surfers' physiological fitness has been primarily laboratory-based ergometer testing, such as assessment of cardiovascular fitness (VO_{2max}) (Farley et al., 2012a; Loveless & Minahan, 2010a; Lowdon et al., 1989; Meir et al., 1991; Mendez-Villanueva et al., 2005) or anaerobic power of the upper-body (Farley et al., 2012a; Loveless & Minahan, 2010b). Recent research has investigated pool-based surfboard sprint paddling to reliably determine peak velocity and time taken to cover specific distances (Loveless & Minahan, 2010b; Secomb, 2012; Sheppard et al., 2012; Sheppard et al., 2013). While ergometer testing provides valuable metabolic information about the physiological and performance characteristics of athletes, field-based pool testing may better simulate actual physical performance measures, such as paddle ability. It has been suggested that ergometer testing protocols can lack ecological validity and fail to replicate the specificity of the sport (Da Silva et al., 2011). Stationary paddle ergometer testing is an open kinetic chain activity, whereas surfboard paddling is considered a closed kinetic chain activity as the surfer 'pulls' their body over the water surface (Farley et al., 2013). As such, a pool based test is not only likely to be more practical to implement with elite athletes but may also have greater discriminatory validity than ergometer testing.

A key physical requirement for surfing athletes is the ability to perform repeated, short powerful bouts of paddling in order to position themselves and catch waves (Loveless & Minahan, 2010b; Lowdon, 1983; Lowdon et al., 1989; Lowdon et al., 1990; Lowdon & Pateman, 1980; Mendez-Villanueva & Bishop, 2005). Previous surfing literature has documented that surfing entails intermittent paddling bouts that vary in intensity and duration

(Farley et al., 2012b; Mendez-Villanueva et al., 2006; Secomb et al., 2014), with surfers performing 10 to 16 (Farley et al., 2012b; 2014) short powerful bursts of paddling (4 – 5 s) to gain momentum for wave take-off (Farley et al., 2012b; Meir et al., 1991; Mendez-Villanueva et al., 2006; Secomb, 2012). Testing surfers' paddling peak velocities within a swimming pool has been reported to range between 1.55 and 1.93 ($m \cdot s^{-1}$) for male and female surfers (Secomb et al., 2013; Sheppard et al., 2013), thus indicating the speeds and distances surfers paddle during each burst. Additionally, surfers also perform repeated bouts of high-intensity paddling (61% of total paddling bouts performed between 1 – 10 s), with short periods of recovery (64% between 1 – 10 s) (Farley et al., 2012b; Mendez-Villanueva et al., 2006; Secomb, 2012) and can compete in up to three heats per day (competitions), lasting between 20 to 40 min each (Farley et al., 2012b; Meir et al., 1991; Mendez-Villanueva et al., 2006). Such findings indicate that surfing is similar in nature to the repeat-sprint activity observed in many field-based team sports.

Field-based team sports such as soccer, rugby (including other forms of the sport) and hockey require participants to repetitively produce and maintain maximal or near maximal sprints of short duration (1 – 7 s), with brief recovery periods, repeated over an extended period of time (60 – 90 min) (Bishop et al., 2001; Spencer et al., 2005). This repeated sprinting, termed repeated sprint ability (RSA) (typically attributed to ≤10% of total activity) has been established as an important fitness component and critical in the outcome of a field-based match (Oliver et al., 2006; Reilly, 1997). Athletes who are able to produce and maintain a higher RSA are likely to outperform and withstand a higher physiological workload than athletes with a lower ability (Bishop et al., 2001). Therefore, given that competitive surfers are engaged in such paddling bouts, it is likely that greater repeat sprint ability will be of benefit to surfing athletes.

In order to design and validate a RSA test with specific sporting dynamics, the protocol should resemble the work to rest ratio and movement mechanics of the sport in question (Turner & Stewart, 2013). As such, time-motion analysis (TMA) via video recordings have allowed researchers to document the detailed movement patterns of team-sport athletes, developing the RSA testing protocols (Spencer et al., 2005). However, there is currently no test established to monitor repeat sprint ability in surfers, which is an important aspect to test given the repeated high-intensity paddling bouts implemented in the sport (Farley et al., 2012b; Meir et al., 1991; Mendez-Villanueva & Bishop, 2005; Secomb et al., 2014). Therefore, using similar protocols and methods from established sports, the purpose of this study was to validate and determine the reliability of a novel repeat sprint paddle test (RSPT) specific to surfing and whether the RSPT provides additional discriminatory information beyond existing tests (i.e. 400m endurance time trial) or correlations (Sheppard et al., 2013). Additionally, it sought to determine whether measurements of blood lactate, total time, peak velocity and fastest 15m time assessed during the RPST are practically relevant for surfing performance and can provide discriminatory data between levels of athletes.

7.2 Methods

7.2.1 Experimental Approach to the Problem

To design a RSPT specific to the movement patterns observed in surfing competitions, TMA data was video recorded then analysed from a World Championship Tour event (n=20 videos recorded side-on to the competition on top of a hill for maximum view of surfers) with previous data also utilised for TMA activity count comparisons (Farley et al., 2012b; Secomb et al., 2014). On average, between 7 and 13 repeat sprint paddle bouts per surfer per heat were identified from TMA, with paddle bout and recovery (non-paddling) times between 2 to 9 s and 2 to 11 s, respectively. A repeated-sprint bout was defined as a minimum of three sprint paddles (less than 10 s), with a mean recovery duration between sprints of less than 15 s. Therefore, the RSPT was designed to mimic the time athletes are performing a maximal bout and resting between bouts (number of efforts and work: rest ratio). Further, given that previous literature has suggested peak paddling velocities of surfers range between 1.55 and 1.93 ($m{\cdot}s^{-1}$) from a one-off burst paddle, a surfer paddling at an average of 1.5 ($m{\cdot}s^{-1}$) for 10 s would cover 15m. Therefore, 10 repeat sprints of 15m were chosen for the RSPT. Test-retest reliability sessions for the RSPT were conducted over two days (separated by minimum of 48 hours). The timed 400m endurance paddle as previously established (Sheppard et al., 2013) was implemented on a third day also separated by 48 hours to determine if there are any correlations with the RSPT and if the RSPT provided relevant discriminatory information.

7.2.2 Participants

A total of 7 internationally competitive level male surfers (23.9 ± 5 y, 71.4 ± 9.2 kg, 1.78 ± 0.03 m, >5 y professionally competing) and 12 recreational male and 6 female surfers (28.9 ± 7.4 y, 71.7 ± 10 kg, 1.77 ± 0.07 m, >5 y surfing experience) volunteered to participate in this study. The study was conducted according to the Declaration of Helsinki and approved by the appropriate institutional ethics committee. Participants were tested following their normal routine of sleep, nutritional and hydration levels. Participants were instructed not to perform any form of weight training (i.e. above 70% 1RM) or prolonged (> 1.5 hours) surfing sessions two hours prior to data collection.

7.2.3 Procedures

Participants performed the RSPT and 400m paddle in an outdoor heated (20 – 24°C) 25m swimming pool, allowing for an easy outline of distances for the subjects to cover and to control for potential environmental variables associated with surfing. All testing was implemented during calm dry days at the same time of day for each participant, with outdoor temperature approximately 20 – 28°C. To standardise trials, participants used the same personal surfboard during the three testing sessions, wore consistent swimwear and started from the same position in the pool. Prior to all testing, participants performed a standardised warm up of 50m of low-intensity paddling on the surfboard, followed by specific 10m sprint paddles at 70, 80 and 90% of maximal effort with approximately 1-min between intervals. Prior to initial RSPT testing on the first day, three slow, self-paced trials were used for familiarisation, followed by a 2-min break. On day two a 2-min break was also used after the standardised warm up before performing RSPT. The two RSPT sessions were used to assess the test-retest reliability. The starting position was stationary, lying prone on the surfboard, approximately 10 cm away from the pool edge with an ankle held by an investigator. Participants were then counted down loudly "3, 2, 1", "Go" with timing and recording of data automatically commenced once the first movement of the horizontal position transducer is detected. Following the conclusion of the test, blood lactate was sampled and recorded via a Lactate Pro Analyser (KDK, Japan) on 8 recreational and 4 competitive participants. Blood lactate was sampled from the left index finger at 1-min, 2-min and 3-min after completing the final sprint. Lactate sampling occurred when the participant was out of the pool standing, with the hand and fingers dried.

7.2.4 Repeat Sprint Test

The RSPT was implemented twice and consisted of participants sprint paddling (no kicking) 15m on their own surfboard, with a horizontal position transducer (I-Rex, Southport, Australia) recording at a displacement frequency of 0.02m, placed at each end of the pool (Sheppard et al., 2012; Sheppard et al., 2013). The line was clipped onto the back of the swimwear at the starting point and a flag marker at each end of the pool was used as a visual indicator of the 15m mark, which athletes had to paddle past with maximal effort. The remaining distance of the 25m pool allowed surfers to glide to the end with enough room to turn their board around. During the time frame between the start of each sprint paddle (30 or 40 s depending on group), a researcher unclipped the extended I-Rex line, then attached the new I-Rex line to allow data collection in both directions

The protocol consisted of 10 x 15m sprint paddles, with each sprint plus recovery lasting either 30 s (competitive surfers) or 40 s (recreational and female surfers). This time difference was implemented after pilot tests revealed several of the recreational participants failed to complete the test in 30 s, whereas competitive surfers' paddle speeds were far greater than recreational surfers, and fatigue was slower. Therefore, a time-frame of 30 s was implemented for the competitive group. Recreational surfers and females maintained the 40 s time-frame, allowing them to complete each sprint with an adequate recovery time (5 – 15 s) for all 10 rounds. Data from each bout of the sprint paddles were recorded onto a portable laptop computer, with further analysis of results completed using Microsoft Excel and SPSS for statistical analysis. The performance measures included; fastest 15m sprint time, peak velocity ($m \cdot s^{-1}$), total time and fatigue index calculated as the average time minus the fastest 15m time. This calculation is an adaption of the percentage decrement score (Fitzsimons, Dawson, Ward, & Wilkinson, 1993).

7.2.5 400m Timed Endurance Paddle Test

The timed 400m endurance paddle test consisted of surfers paddling non-stop over a 20m up and back course, with participants completing a 180 degree turn at the buoys (20m apart) whist remaining prone on their board, ensuring continuous paddling to a total of 400m with the total time to complete 400m recorded (Sheppard et al., 2013). The time to complete the paddle test allows for determination of each subjects average aerobic speed, which reflects individual endurance capabilities.

7.2.6 Statistical Analyses

Mean and ± standard deviations (±SD) were calculated for the variables; total time, fastest 15m time, peak velocity and fatigue index. Intra-class correlation coefficient (ICC), typical error as a coefficient of variation (CV%) and typical error (TE) with 90% confidence limits (CL) were used to determine the between days repeated test reliability of the dependent variables using Hopkins spreadsheet (Hopkins, 2000). In addition, the smallest worthwhile change (SWC) was calculated as 0.20 x between subjects' SD. Discriminatory validity of the RSPT performance variables between competitive and recreational surfers were determined by statistically analysing day 1 and day 2 results via Independent Samples T Test using statistical analysis package (SPSS, Version 22.0; Chicago, IL). Pearson's Correlations (*r*) between 400m time and RSPT variables were statistically analysed using SPSS, statistical significance defined as $p \leq 0.05$. CV% was categorised as poor (≥10%), moderate (5 – 10%) or good (≤5%) based on values used in previous research (Duthie et al., 2003; Johnston et al., 2014). The strength of the ICC scores was based on Pearson's correlation coefficients and regarded as trivial (0.0), small (0.1), moderate (0.3), large (0.5), very large (0.7), nearly perfect (0.9) and perfect (1.0) (Hopkins, 2008).

7.3 Results

The descriptive analysis, including means and ± SDs for both the recreational and competitive groups, along with the ICC, TE and CV% and SWC for the RSPT variables of interest are presented in Table 14. Blood lactate measures recorded from 8 recreational, 4 competitive surfers (*n*=12) reported a 0.40 ± 0.10 mmol/L difference between day-to-day trials.

Table 14: Reliability of performance during the repeat sprint paddle test in recreational and competitive surfers

Variable	Day 1	Day 2	ICC (CL 90%)	CV% (CL 90%)	TE (CL 90%)	SWC
Recreational Surfers (n=18)						
Total Time (s)	115.27 ± 13.19	115.51 ± 13.86	0.98 (0.95 – 0.99)	1.7 (1.4 – 2.5)	0.15 (0.15 – 0.21)	2.70
Fastest 15m (s)	10.56 ± 0.82	10.64 ± 0.91	0.95 (0.89 – 0.98)	1.9 (1.5 – 2.7)	0.17 (0.13 – 0.24)	0.17
Peak Velocity ($m \cdot s^{-1}$)	1.63 ± 0.14	1.62 ± 0.14	0.97 (0.93 – 0.99)	1.7 (1.3 – 2.4)	0.15 (0.11 – 0.21)	0.03
Fatigue Index	0.95 ± 0.72	0.93 ± 0.72	0.73 (0.47 – 0.87)	67.5 (49.9 – 105.9)	0.55 (0.46 – 0.76)	0.14
Competitive Surfers (n=7)						
Total Time (s)	106.60 ± 7.23	105.91 ± 7.29	0.99 (0.97 – 1.00)	0.8 (0.8 – 1.6)	0.12 (0.09 – 0.24)	1.46
Fastest 15m (s)	9.65 ± 0.51**	9.63 ± 0.44*	0.91 (0.68 – 0.98)	1.8 (1.3 – 3.6)	0.38 (0.26 – 0.72)	0.09
Peak Velocity ($m \cdot s^{-1}$)	1.75 ± 0.08**	1.77 ± 0.09**	0.93 (0.73 – 0.98)	1.7 (1.2 – 3.3)	0.35 (0.24 – 0.66)	0.02
Fatigue Index	1.01 ± 0.44	0.96 ± 0.42	0.81 (0.3 – 0.95)	26.8 (17.8 – 57.7)	0.52 (0.36 – 1.0)	0.08
Blood Lactate Measures (n=12, 72 samples)						
Bla mmol/L	8.1 ± 2.5	7.7 ± 2.6	0.73 (0.55 – 0.84)	23.7 (19.2 – 31.1)	0.53 (0.44 – 0.68)	0.51

Note: ICC = Intra-class correlation coefficient; CV% = typical error as coefficient of variation; TE = typical error is provided with 90% confidence limits (90% CL); SWC = smallest worthwhile change (SWC). * = significantly different to recreational surfers p=≤0.01 (2-tailed); ** significantly different to recreational surfers p=≤0.05 (2-tailed).

The discriminatory validity between the competitive level surfers and recreational surfers completing the RSPT on different times is presented in Table 15, demonstrating a measure of ecological validity.

Table 15: Discriminatory validity between competitive level surfers and recreational surfers tested on different times

	95% Confidence Interval of the Difference					
Variable	**Day 1**	**Lower**	**Upper**	**Day 2**	**Lower**	**Upper**
Total Time (s)		-2.3	19.7		-1.9	21.1
Fastest 15m (s)		0.21	1.6		0.26	1.76
Peak Velocity ($m \cdot s^{-1}$)		-0.23	-0.004		-0.27	-0.03

The 400m paddle times for the 18 recreational surfers was significantly (p=≤0.01) correlated with all of the RSPT performance measures (Table 16). Likewise, significant correlations (p=≤0.01) were observed between all RSPT performance measures (Table 16).

Table 16: Intercorrelation matrix between the repeat sprint paddle test performance variables and the 400 m endurance paddle time between 18 surfers

Variable	400m time	Total RSPT time	Fastest 15m	Peak Velocity ($m \cdot s^{-1}$)	Ave 15m time (day 1)	Ave 15m time (day 2)	Ave PV (day 1)	Ave PV (day 2)
400m time	1.00							
Total RSPT time	-.89*	1.00						
Fastest 15m	.72*	.90*	1.00					
Peak Velocity (PV) ($m \cdot s^{-1}$)	-.71*	-.88*	-.98*	1.00				
Ave 15m time (day 1)	.91*	.99*	.86*	-.84*	1.00			
Ave 15m time (day 2)	.89*	.99*	.92*	-.88*	.98*	1.00		
Ave PV (day 1)	-.92*	-.98*	-.87*	.87*	-.98*	-.96*	1.00	
Ave PV (day 2)	-.88*	-.98*	-.94*	.92*	-.95*	-.98*	.97*	1.00

*. Correlation is significant at the 0.01 level (2-tailed).

7.4 Discussion

The development of a test determining surfing athletes' repeat sprint paddle ability, which to our knowledge had not been done before, was warranted to advance the understanding of the physical capabilities of surfers. Yet, to ensure that this test is useful to athletes, coaches and researchers it is important to determine the reliability and discriminatory validity of performance measures from this test. Therefore, the purpose of this study was to develop and determine the reliability of a novel RSPT. Additionally, it examined whether any of the performance variables and blood lactate, provided discriminatory validity on surfing athletes' paddling performance. The study also examined whether any of the RSPT performance variables were correlated to a previously used 400m endurance paddle test and determine if such measures provided additional discriminatory information beyond the existing test. In view of the results, the RSPT should be complementary to the existing surfing specific performance tests described in previous literature (Sheppard et al., 2012).

The results from the study indicate that the novel RSPT using a horizontal position transducer at each end of the pool is reliable in recreational and competitive surfers for determining RSPT total time, best 15m time and PV ($m \cdot s^{-1}$). The RSPT total time, best 15m time and PV ($m \cdot s^{-1}$) determined for the 12 recreational male and six recreational female surfers were established to be reliable (CV%=≤1.9, TE=≤0.17 s, ICC=≥0.95) on separate days. Furthermore, the performance variables of 7 competitive surfers working on a 30 s time limit were also reliable on separate days (CV%=≤1.8, TE=≤0.38 s, ICC=≥0.91) and therefore indicating that the RSPT may be useful as criterion measures of athlete performance. These results are also comparable to water polo studies (TE=0.44 s, CV%=1.2, ICC=0.93, repeated sprints (Tan, Polglaze, & Dawson, 2010); ICC=0.88, SEM=0.13-0.49 s, CV%=6-7, agility tests (Tucher, Castro, Garrido, & Silva, 2014); CV%=5.4, shuttle test (Mujika, McFadden, Hubbard, Royal, & Hahn, 2006)).

The small TE and SWC values for the RSPT performance variables reported in this study indicates the practicality of the test in determining performance enhancement measures for coaches and sport scientists. The small TE indicates that any results recorded for an athlete that are greater than the TE value are highly likely due to training/de-training induced changes and not biological variables and technical error inherent in the test (Sheppard et al., 2013). The change greater than the TE means that the change has exceeded the combination of biological and technical error inherent in the test. For example, a decrease in the total paddling time by 3 s for a professional surfer would be regarded as 'real and worthwhile' change (Spencer, Fitzsimons, Dawson, Bishop, & Goodman, 2006). Likewise, an increase in surfers' PV by 0.05 ($m \cdot s^{-1}$) would be classified as a change too. This is because the differences are greater than both the TE and SWC found in this study for the performance measures. A performance change by 3 s likely represents an improved performance, however, it is difficult to isolate where this comes from in a performance test that is limited by a combination of factors (e.g. aerobic, anaerobic, peak velocity, etc.) as highlighted by the correlated factors in Table 16. However, 5 weeks of strength training does appear to increased paddling speed over the 5, 10 and 15m while a control group became slower (d=0.71, 0.51, 0.4 respectively). Additionally, improvements were also reported in 400m paddling performance compared to control (d=0.72). However, the magnitude of performance increases appears dependent on initial strength levels with differential responses between strong and weaker athletes (Coyne et al., 2016 (In Press)). Equally, an increase in PV would aid in the ability to maintain and produce enough power for achieving early high-speed, efficient entry into waves (Sheppard et al., 2013).

Comparisons between the pool-based RSPT and laboratory-based ergometer paddling indicates that RSPT is just as reliable as ergometer tests (Farley et al., 2012a; Loveless & Minahan, 2010b; Morton & Gastin, 1997; Swaine, 2000). Additionally, it was found that the RSPT discriminates between levels of surfing ability, with recreational surfers having slower times and lower peak velocities compared to competitive surfers, even with greater time (40 s) to complete the test. This is in contrast to ergometer studies, where the results have not been able to detect maximal aerobic differences between groups of higher and lower surfing ability (Loveless & Minahan, 2010a; Mendez-Villanueva et al., 2005), or a relationship to the end of year season rank (Barlow et al., 2015; Farley et al., 2012a; Mendez-Villanueva et al., 2005). Therefore, the novel test described in this study produces discriminatory validity and could form part of a specific battery of pool-based tests for surf athletes that can be easily implemented in the pool. Finally, significant correlations were identified between the RSPT performance measures and the 400m time-trial test (Sheppard et al., 2013) indicating that performance in the RPST is probably influenced by aerobic capacity. The ability to maintain a high speed over repeated efforts is likely to be related to the individuals' aerobic capacity. While this study did not specifically assess the athletes' aerobic and anaerobic metabolism during these tests, it would be recommended in future research. Understanding the physiological responses to the 400m paddle and RSPT would provide a better understanding if metabolic responses to such paddling scenarios are different, at this stage it seems that both are underpinned by aerobic capacity. However, the RSPT does contribute with additional information such as maximal sprint speed, anaerobic performance, repeat sprint ability, rate of acceleration and fatigue index, with two different protocols required for competitive and recreational surfers. However, further research is warranted to ascertain if the RSPT should be added to the surf athletes' testing protocol and used in conjunction with the 400m paddle test.

7.5 Conclusion

In summary, the novel RSPT to measure repeated sprint paddle ability in surfing athletes was found to be highly reliable between day-to-day testing sessions. The RSPT was shown to discriminate between levels of surfing (competitive trials on 30 s, recreational on 40 s) and the total time of the test showed a correlation (*r*=0.89) to the continuous 400m time trial test also used for surfing athletes. Furthermore, the low TE and SWC that were found in this study, indicate that small adaptations are likely to be accurate changes from training/de-training and could form part of a specific surfing battery of tests.

7.6 Practical Applications

The study developed and evaluated a novel repeat sprint test that was found to be a reliable measure of paddle performance measures (total time, best 15m sprint time, peak velocity) and monitor fatigue (average time minus the best 15m time). The test can be easily implemented to test surfing athletes to accurately measure sprint paddling performance, with only two linear encoders. Although the total time of the RSPT was significantly correlated with (*r*=0.89) the 400m endurance paddle test, the RSPT also seems to provide additional information, specifically with regards to maximal sprint performance. The outcomes from this study resulted in the establishment of a repeat sprint testing protocol that can form part of a specific battery of pool-based tests for recreational, female and competitive surfers. Further, the RSPT for surf athletes can also be used as a conditioning training tool due to the nature of the test and training for specific surfing locations where repeated sprint paddling is warranted. As such, coaches and sport scientists can adopt the RSPT wholly, or modify, as well as expand upon its use with future research, such as investigating metabolic responses to the test and compare performance between the professional, recreational and male surfers.

Chapter 8: Study 4: Tracking 6 Weeks of Training/Surfing Sessions of Adolescent Competitive Surfers: Just what are these young surfers up to?

Due to Copyright reasons,

Chapter 8 is unavailable in this version of the thesis.

The chapter was originally published as:

Farley, O. R. L., Secomb, J. L., Parsonage, J., Lundgren, L., Abbiss, C., & Sheppard, J. M. (2015). Tracking 6 weeks of training/surfing sessions of adolescent competitive surfers: Just what are these young surfers up to? *Journal of Australian Strength and Conditioning*, 23(6), 98-100.

Chapter 9: Study 5: Five Weeks of Sprint and High Intensity Interval Training Improves Paddling Performance in Adolescent Surfers

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Chapter 10:
Overall Summary and Conclusions

With the growth in professional elite surfing, the sport needs to be understood in greater depth to physically prepare these athletes to higher capabilities. However, literature as such is profoundly limited. The objectives of this thesis were fivefold and designed to; i) determine the reliability and validly of custom-made GPS units; ii) perform an in-depth performance analysis determining the workloads (i.e. exercise durations, distances, velocity of movements and work to relief ratios) experienced during three different surfing competitions; iii) develop and assess the reliability and relevance of an innovative, repeat-sprint paddle test to measure surfing athletes' performance; iv) determine surfing and structured training hours adolescent surfers currently perform on a weekly basis and v) examine the effects of two different paddle training protocols (sprint interval training and high intensity interval training) on adolescent surfers' aerobic and repeat sprint paddle ability performance.

Study 1 determined the validly and inter-unit reliability of GPS units. Such research was important for determining how accurate and reliable the GPS units were before using them within the performance analysis (Study 2). It was discovered that the custom-made units had better reliability than GPS units utilised in previous studies. Furthermore, it was noted that such units are still likely to exhibit an error at high speeds $\geq$20 km$\cdot$h^{-1} and underestimations in total distance at slower speeds $\leq$6 km$\cdot$h^{-1}. Following the results of Study 1, these units were implemented in Study 2 in the examination of three surfing competitions using performance analysis methods (TMA and GPS) to determine workloads and differences between surf break locations. The principle finding of Study 2 was that point-breaks have longer continuous periods of paddling and longer wave rides, whereas a beach-break exhibited significantly higher work to relief ratio and total distance covered. Ultimately, the workloads and demands experienced during competitive surfing differed between locations and types of surf break. This information is important when developing surfing drills and conditioning methods to prepare these athletes for the disparate demands, such as training for a point-break competition involving longer durations of continuous paddling and short high intensity workloads for a beach-break. Additionally, the results from Study 2 aided in the development of an appropriate and valid repeat sprint paddle test (RSPT) that reflected the repeated demands of surfing and to test this ability in surfers (Study 3).

The third study developed and evaluated an innovative repeat sprint paddle test (RSPT) which mimicked the time surfers perform a maximal bout and rest between bouts. Such research was implemented to determine if the RSPT provided additional discriminatory information beyond existing tests. The study found the test to be highly reliable in measuring paddle performance measures (total time, best 15m sprint time, peak velocity), fatigue (average time minus best 15m time) and discriminated between levels of surfing. Low typical error and smallest worthwhile change found in this study allow accurate indication of adaptations due to training/de-training. The RSPT contributed additional information such as maximal sprint speed, anaerobic performance, repeat sprint ability, rate of acceleration and fatigue index, with two different protocols required for competitive and recreational surfers. Additionally, the test can also serve as a conditioning tool for surfers. However, further research is warranted to provide a better understanding if metabolic responses to the paddling scenarios (i.e. RSPT, 400m) are different.

Limited knowledge exists around structured training hours performed by adolescent surfers, therefore the pilot study (study 4) questioned eight adolescent surfers twice a week for six weeks, reporting on surfing hours and physical training hours. Specifically, participants provided the number of hours spent free surfing, being coached, competing, strength training, conditioning and performing balance work. It was discovered that adolescent surfers were implementing on average, 14 hours extra surfing than any form of land-based training, with approximately only 1 hour per week doing any form of strength work. Some athletes did not do any form of structured training, therefore, the implementation of structured training methods such as paddle training are warranted, especially given the importance of it within surfing.

Following the conclusions of Study 4, an attempt to increase the amount of structured training was implemented. Training for improved paddling enhancement is warranted and the results of Study 2 aided in establishing training loads of the paddle training programmes with the RSPT from Study 3 implemented in performance measure testing (Study 5). The fifth study determined the implications of structured training on the paddling abilities of adolescent surfers. The two different surfboard paddle modules consisted of either 10 s bursts with 30 s rest (Sprint interval training (SIT)) or 30 s bursts with 30 s rest (high intensity interval training (HIT)) implemented twice a week for five weeks in an ocean inlet. Surfing athletes significantly decreased their 400m endurance paddle time during HIT and decreased the total RSPT time during SIT. Such results indicate that the tests can possibly discriminate between aerobic and anaerobic training adaptations, with aerobic gains likely from HIT and anaerobic gains from SIT. The training modules were practical to implement and demonstrated improvements in surfing athletes' endurance paddle ability and anaerobic repeat sprint paddle ability, which are key aspects of the sport.

Overall, this thesis established greater in-depth information on competitive surfing, an innovative and reliable test to assess repeat sprint ability and two training methods that produced beneficial sprint and endurance paddle improvements. With an ever-increasing rise in professionalism in surfing, such findings support implementing the testing and training protocols in a performance curriculum to measure and improve upon the physical abilities of surfers. From a training perspective, surfers expecting to surf at a point-break could work on longer durations of continuous paddling involving HIT. Whereas for a beach-break scenario and small surf conditions, surfers could emphasis training, involving short high intensity workloads (i.e. SIT) and repeated long sprint paddling for waves. It is recommended that future studies investigate speeds, acceleration and forces generated when performing airs through synchronised performance analysis methods. Investigate metabolic measures during the pool tests (i.e. RSPT, 400m and 15m sprint) and paddle training, as well as the implications of longitudinal training with HIT and SIT methods and with older elite athletes.

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Appendix 1: Ethics Approval Letter

Project Number: 10181 FARLEY
Project Name: Assessment of Competitive Requirements, Fitness and Trainability of Anaerobic and Aerobic Capacity of Surfers

Student Number: 10324137

The ECU Human Research Ethics Committee (HREC) has reviewed your application and has granted ethics approval for your research project. In granting approval, the HREC has determined that the research project meets the requirements of the *National Statement on Ethical Conduct in Human Research*.

The approval period is from 23 September 2013 to 20 March 2015.

The Research Assessments Team has been informed and they will issue formal notification of approval. Please note that the submission and approval of your research proposal is a separate process to obtaining ethics approval and that no recruitment of participants and/or data collection can commence until formal notification of both ethics approval and approval of your research proposal has been received.

All research projects are approved subject to general conditions of approval. Please see the attached document for details of these conditions, which include monitoring requirements, changes to the project and extension of ethics approval.

Please feel free to contact me if you require any further information.

Regards

Sue

Sue McDonald, Research Ethics Support Officer, Office of Research & Innovation, Edith Cowan University, 270 Joondalup Drive, Joondalup, WA 6027

Email: research.ethics@ecu.edu.au Tel: +61 08 6304 5122 | Fax: +61 08 6304 5044 | CRICOS IPC 00279B

Appendix 2: Participant Medical Questionnaire

Assessment of Competitive Requirements, Fitness and
Trainability of Anaerobic and Aerobic Capacity of Surfers
EDITH COWAN UNIVERSITY
SCHOOL OF EXERCISE AND HEALTH SCIENCES
MEDICAL QUESTIONNAIRE

Name: ___________________________ Age: _____yr Weight: ____kg Height: ___cm

Briefly describe the type and amount of exercise you do.
Type: ____
Amount: ____

Do you smoke? YES NO

Have you smoked in the past? YES NO

Have you ever been diagnosed with –

being overweight? YES NO

high blood pressure? YES NO

diabetes? YES NO

asthma? YES NO

any bleeding disorders? YES NO

Do you have any reason to believe that you are more at risk of cardiovascular disease than a normal member of the population of the same age and sex?

YES NO

If YES please give details

____

____

Have you ever had rheumatic fever?

YES NO

If YES please give details

____

____

Have you ever experienced heat exhaustion or heat stroke?

YES NO

If YES please give details

____

____

Is there anything that you are aware of that may limit your capacity to exercise? (e.g. Chronic back pain and/or other joint pain, severe headaches?)

YES NO

If YES please give details

___

___

Do you have any allergies?

YES NO

If YES please give details

___

___

Are you currently on any prescribed or non-prescribed medications?

YES NO

If YES please give details

___

___

Have you suffered from any viral infections, chronic tiredness or donated blood in the past two months?

YES NO

If YES please give details

___

___

Do you have any other complaint or any other reason that you know of which you think may prevent you from participating in and completing this experiment?

YES NO

If YES please give details

___

___

I believe that the information that I have supplied is true and correct.

Print Name **Signed** **Date**

___ ___ ___

Appendix 3: Information Letter and Inform Consent Study 1

Information Letter to Participants

Title of the project

"An in-depth performance analysis into the workloads of competitive surfing: A performance analysis of three surfing competitions"

Researchers and Contact details

Oliver Farley, MSe
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Description of the research project

The aim of this project is to examine the physical and external loads, activity patterns; distances covered and exercise duration of elite surfers during competition using performance analysis.

You have been selected by way of personal contact with one of the investigators in this project and through Surfing Australia High Performance Centre and local board rider clubs to participate in this study. To participate in the study, you will firstly need to complete the medical questionnaire. If you have any contraindications, you will be asked to obtain a medical clearance from your general practitioner prior to participation or be excluded from the study. If you are under the age of 18 years at the commencement of the study a parent/guardian signature of consent will need to be provided prior to participation.

All testing will be conducted at different surf beach locations. Participants will be monitored during all heats within sanctioned competitions. Organisers at the events will have first aid and CPR qualifications. During these sessions participants will be asked to wear a GPS unit and we will film your surfing from the beach. After the surf session, data from the GPS unit will be downloaded to a laptop for analysis of speeds, distance travelled etc.

During each testing session:

- Speeds, distances velocity of movements will be continuously monitored. GPS unit will be positioned on the upper vertebrae or fastened around your arm.
- You will be continuously filmed for each heat.

You will benefit from participating in this study by gaining a better understanding of your surfing performance. Where possible you will be provided with information regarding your speeds, heart rates, distances covered and time spent performing the various surfing activities.

Confidentiality of information

The information collected in this study will be used to prepare a scientific report to be published in an academic journal. The information will only be available to Oliver Farley and his team of researchers (supervisors). Your personal data will be assigned an identification code, such that only those people directly involved in collecting information for the study will be able to recognise which person the information pertains to. The information collected in this study will be stored under file in the School of Exercise and Sport Sciences for a period of 5 years at ECU. After the study has finished the information collected during the course of the study will be destroyed.

Results of the research study

The data collected in this study will be summarised as average data for all participants. There will be no individual data presented, which means that your personal information cannot be identified. The data will be presented at conferences and as a scientific report to be published in an academic journal. If you request it, you will receive a summary of your own personal information and a group summary explaining the findings of the study.

Voluntary participation

Your participation in this study is entirely voluntary. No explanation or justification is needed if you choose not to participate.

Withdrawing consent to participate

You are free to withdraw your consent to further involvement in the research project at any time. If you choose to withdraw, you have the right to request that any personal information collected up to that point in the study is returned to you without question.

Questions and/or further information

If you have any questions or require any further information about the research project, please contact Oliver Farley on 0467424379 or email: oliver@surfingaustralia.com

Independent contact person

If you have any concerns or complaints about the research project and wish to talk to an independent person, you may contact:

Research Ethics Officer
Human Research Ethics Committee
Edith Cowan University
100 Joondalup Drive
JOONDALUP WA 6027
Phone: (08) 6304 2170
Email: research.ethics@ecu.edu.au
If you are interested in taking part in this study, then please read and sign the Informed Consent document and return it to Oliver Farley in person or by post at the address provided at the beginning of this letter.

Informed Consent Document

Title of the project

"An in-depth performance analysis into the workloads of competitive surfing: A performance analysis of three surfing competitions"

Researchers and Contact details

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Statement indicating consent to participate

I confirm the following:

- I have been provided with a copy of the Information Letter, explaining the research study
- I have read and understood the information provided
- I have completed the medical questionnaire and am not aware of any conditions that may prevent me from completing this experiment.
- I have been given the opportunity to ask questions and I have had any questions answered to my satisfaction
- I am aware that if I have any additional questions I can contact the research team
- I understand that participation in the research project will involve:
    - Wearing a GPS unit while being videoed
    - Being monitored competitions
- I understand that my information provided will be kept confidential and that my identity will not be disclosed without consent
- I understand that the information provided will only be used for the purposes of this research project and I understand how the information is to be used
- I understands that I am free to withdraw from further participation at any time, without explanation or penalty
- I freely agree to participate in the project

Signed ………………………………………………

Name……………………………………….……..….... **Date**…………..…

Parent/guardian Signed ……………………………………………..…

Name……………………………………....…………... **Date**………...……

Signed by member of research team ……………………………………………….….

Appendix 4: Information Letter and Inform Consent Study 3

Information Letter to Participants

Title of the project

"The repeat-sprint paddle test: A protocol for measuring surfing athletes' sprint paddle performance."

Researchers and Contact details

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Description of the research project

The aim of this project is to develop a novel repeat sprint paddle test. The study will refine the current aerobic and anaerobic testing fitness tests used with the national program (15-meter sprint paddle, 400-meter endurance paddle).

You have been selected by way of personal contact with one of the investigators in this project and through Surfing Australia High Performance Centre and local board rider clubs to participate in this study. To participate in the study, you will firstly need to complete the medical questionnaire. If you have any contraindications, you will be asked to obtain a medical clearance from your general practitioner prior to participation or be excluded from the study. If you are under the age of 18 years at the commencement of the study a parent/guardian signature of consent will need to be provided prior to participation.

As a participant in this study, you will be involved in 3 testing sessions. All testing will be conducted under supervision at the Hurley Surfing Australia High Performance Centre (HPC). During this time, repeated measure (2 separate days) of the repeat sprint must be completed within 2 days apart and you will need to attend the HPC on 3 separate occasions. Testing sessions will last approximately 30 min depending on your level of fitness. Prior to testing you will have your height and body weight measured.

The 400-meter endurance paddle test (day 3) is based over 20m up and back course, with a total of 400m accomplished.

The repeat sprint paddle consists of performing 10 repetitions of 15m maximal high-intensity paddling separated by either 30 or 40 seconds of rest. After the test a blood lactate sample will be taken if you agree to have it taken.

During the different testing sessions in this study:

- You will have a horizontal position transducer attached to your shorts during 15m sprint paddle test.
- You will be asked about your perceived exertion
- Your blood lactate will be taken by withdrawing a small amount of blood from your index finger.

During the testing session it is possible that you may experience fatigue and muscle soreness/burning sensation from the exercising. During pool testing researchers will have CPR qualifications to minimize safety concerns. Researchers supervising pool testing sessions will have first aid and CPR qualifications. From participation in the study you may experience tiredness, muscular fatigue and slight pain from finger-stick blood sampling. The blood sampling will be conducted by qualified personnel using standard sterile procedures.

You will benefit from participating in this study by gaining fitness from the exercise and gain a better understanding of your own fatigue during such exercise. Where possible you will also be provided with information regarding your sprint times, endurance times and blood lactate

Confidentiality of information

The information collected in this study will be used to prepare a scientific report to be published in an academic journal. The information will only be available to Oliver Farley and his team of researchers. Your personal data will be assigned an identification code, such that only those people directly involved in collecting information for the study will be able to recognise which person the information pertains to. The information collected in this study will be stored under file in the School of Exercise and Sport Sciences for a period of 5 years at ECU. After the study has finished the information collected during the course of the study will be destroyed.

Results of the research study

The data collected in this study will be summarised as average data for all participants. There will be no individual data presented, which means that your personal information cannot be identified. The data will be presented at conferences and as a scientific report to be published in an academic journal. If you request it, you will receive a summary of your own personal information and a group summary explaining the findings of the study.

Voluntary participation

Your participation in this study is entirely voluntary. No explanation or justification is needed if you choose not to participate.

Withdrawing consent to participate

You are free to withdraw your consent to further involvement in the research project at any time. If you choose to withdraw, you have the right to request that any personal information collected up to that point in the study is returned to you without question.

Questions and/or further information

If you have any questions or require any further information about the research project, please contact Oliver Farley on 0467424379 or email: oliver@surfingaustralia.com

Independent contact person

If you have any concerns or complaints about the research project and wish to talk to an independent person, you may contact:

Research Ethics Officer
Human Research Ethics Committee
Edith Cowan University
100 Joondalup Drive
JOONDALUP WA 6027
Phone: (08) 6304 2170
Email: research.ethics@ecu.edu.au

If you are interested in taking part in this study, then please read and sign the Informed Consent document and return it to Oliver Farley in person or by post at the address provided at the beginning of this letter.

Informed Consent Document

Title of the project

"The repeat-sprint paddle test: A protocol for measuring surfing athletes' sprint paddle performance"

Researchers and Contact details

Oliver Farley, MSe
Hurley Surfing Australia High Performance Centre
PO Box 1613
Kingscliff NSW 2487
M: 0467424379
T: +61 2 66 71 0000

Dr Jeremy Sheppard, Ph.D.
Senior lecturer
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Edith Cowan University
Hurley Surfing Australia High Performance Centre
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T: +61 2 66 71 0000

Dr Chris Abbiss, Ph.D.
School of Exercise and Health Sciences
Edith Cowan University
School of Exercise and Health Sciences
270 Joondalup Drive
Joondalup WA, 6027
T: +61 8 63 04 5740

Statement indicating consent to participate

I confirm the following:

- I have been provided with a copy of the Information Letter, explaining the research study
- I have completed the medical questionnaire and am not aware of any conditions that may prevent me from completing this experiment.
- I have read and understood the information provided
- I have been given the opportunity to ask questions and I have had any questions answered to my satisfaction
- I am aware that if I have any additional questions I can contact the research team
- I understand that participation in the research project will involve:
    - A number of testing sessions (3-4 separate occasions)
    - 400-meter timed endurance paddle
    - Repeat sprint paddle 10 times 15m with horizontal position transducer attached to your shorts
    - Having blood lactate samples taken from my finger
- I understand that my information provided will be kept confidential and that my identity will not be disclosed without consent
- I understand that the information provided will only be used for the purposes of this research project and I understand how the information is to be used
- I understands that I am free to withdraw from further participation at any time, without explanation or penalty

- I freely agree to participate in the project

Signed ………………………………………………

Name………………………………………..……..…..... **Date**…………...…

Parent/guardian Signed …………………………………………..…

Name……………………………………....…………... **Date**………...……

Signed by member of research team …………………………………………………..….

Appendix 5: Information Letter and Inform Consent Study 5

Information Letter to Participants

Title of the project

"Training methods for improved athletic performance"

Researchers and Contact details

Oliver Farley, MSe
Hurley Surfing Australia High Performance Centre
PO Box 1613
Kingscliff NSW 2487
M: 0467424379
T: +61 2 66 71 0000

Dr Jeremy Sheppard, Ph.D.
Senior lecturer
School of Exercise and Health Sciences
Edith Cowan University
Hurley Surfing Australia High Performance Centre
PO Box 1613
Kingscliff NSW 2487
T: +61 2 66 71 0000

Dr Chris Abbiss, Ph.D.
School of Exercise and Health Sciences
Edith Cowan University
School of Exercise and Health Sciences
270 Joondalup Drive
Joondalup WA, 6027
T: +61 8 6304 5740

Description of the research project

The aim of this project is to examine if specific repeat effort paddle training improves surfing performance. The training study will investigate and compare the effects of two training programs high intensity interval training (HIT) and Sprint interval training (SIT) (i.e. 10s vs. 30s efforts).

You have been selected by way of personal contact with one of the investigators in this project and through Surfing Australia High Performance Centre to participate in this study. To participate in the study, you will firstly need to complete the medical questionnaire. If you have any contraindications, you will be asked to obtain a medical clearance from your general practitioner prior to participation or be excluded from the study. If you are under the age of 18 years at the commencement of the study a parent/guardian signature of consent will need to be provided prior to participation.

This study will involve in a number of testing and training sessions which will be conducted over an 8-week period. During this period, you will perform 6 weeks (2 times per week) of structured high-intensity of either Hit or SIT. All training will be conducted under supervision at Palm Beach Currmbin High School. During this time, the first and last week of the allocated training period will be allocated for fitness testing.

The high intensity interval training consists of participants performing a 30 second maximal burst, interspaced with 30 seconds rest with 2-minute rest between sets. The participants in the sprint interval training group will perform a repeat sprint of 10 seconds of work and 30 seconds of rest, with 2-minute rest between sets. Training sessions will last approximately 30 min.

Prior to and following training you will be asked to attend testing sessions, where you will have your height and body weight measured. In addition, you will also be asked to perform a maximal 15m repeat sprint paddle test and a 400m endurance test.

The repeat sprint paddle consists of 10 repetitions of maximal high-intensity paddling separated by 40 seconds of rest. The 400m endurance test is paddling a total distance of 400m non-stop.

During allocated physiological response testing during training sessions:

- You will have a horizontal position transducer attached to your shorts during 15m sprint paddle.
- You will be asked about your perceived exertion.

During the testing session it is possible that you may experience fatigue and muscle soreness/burning sensation from the exercising and slight pain from blood sampling. Researchers supervising pool testing sessions will have first aid and CPR qualifications. From participation in the study you may experience tiredness and muscular fatigue.

You will benefit from participating in this study by gaining fitness from the exercise and gain a better understanding of your own fatigue during such exercise. Where possible you will also be provided with information regarding your sprint times and endurance times and overall performance.

Confidentiality of information

The information collected in this study will be used to prepare a scientific report to be published in an academic journal. The information will only be available to Oliver Farley and his team of researchers. Your personal data will be assigned an identification code, such that only those people directly involved in collecting information for the study will be able to recognise which person the information pertains to. The information collected in this study will be stored under file in the School of Exercise and Sport Sciences for a period of 5 years at ECU. After the study has finished the information collected during the course of the study will be destroyed.

Results of the research study

The data collected in this study will be summarised as average data for all participants. There will be no individual data presented, which means that your personal information cannot be identified. The data will be presented at conferences and as a scientific report to be published in an academic journal. If you request it, you will receive a summary of your own personal information and a group summary explaining the findings of the study.

Voluntary participation

Your participation in this study is entirely voluntary. No explanation or justification is needed if you choose not to participate.

Withdrawing consent to participate

You are free to withdraw your consent to further involvement in the research project at any time. If you choose to withdraw, you have the right to request that any personal information collected up to that point in the study is returned to you without question.

Questions and/or further information

If you have any questions or require any further information about the research project, please contact Oliver Farley on 0467424379 or email: oliver@surfingaustralia.com

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Research Ethics Officer
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100 Joondalup Drive
JOONDALUP WA 6027
Phone: (08) 6304 2170
Email: research.ethics@ecu.edu.au

If you are interested in taking part in this study, then please read and sign the Informed Consent document and return it to Oliver Farley in person or by post at the address provided at the beginning of this letter.

Informed Consent Document

Title of the project

"Training methods for improved athletic performance"

Researchers and Contact details

Oliver Farley, MSe
Hurley Surfing Australia High Performance Centre
PO Box 1613
Kingscliff NSW 2487
M: 0467424379
T: +61 2 66 71 0000

Dr Jeremy Sheppard, Ph.D.
Senior lecturer
School of Exercise and Health Sciences
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Dr Chris Abbiss, Ph.D.
School of Exercise and Health Sciences
Edith Cowan University
School of Exercise and Health Sciences
270 Joondalup Drive
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T: +61 8 63 04 5740

Statement indicating consent to participate

I confirm the following:

- I have been provided with a copy of the Information letter, explaining the research study and understood the information provided
- I have completed the medical questionnaire and am not aware of any conditions that may prevent me from completing this experiment.
- I have been given the opportunity to ask questions and I have had any questions answered to my satisfaction
- I am aware that if I have any additional questions I can contact the research team

- I understand that participation in the research project will involve:
  - 12 training sessions which will be conducted over a 6-week period
  - Asked for perceived exertion
  - During training programme, you will be tested at the beginning and again the week after completion of the 6-week programme on the following test:
    - 15-meter repeat sprint paddle with horizontal position transducer attached to a rash shirt
    - 400m endurance paddle
- I understand that my information provided will be kept confidential and that my identity will not be disclosed without consent
- I understand that the information provided will only be used for the purposes of this research project and I understand how the information is to be used
- I understands that I am free to withdraw from further participation at any time, without explanation or penalty
- I freely agree to participate in the project

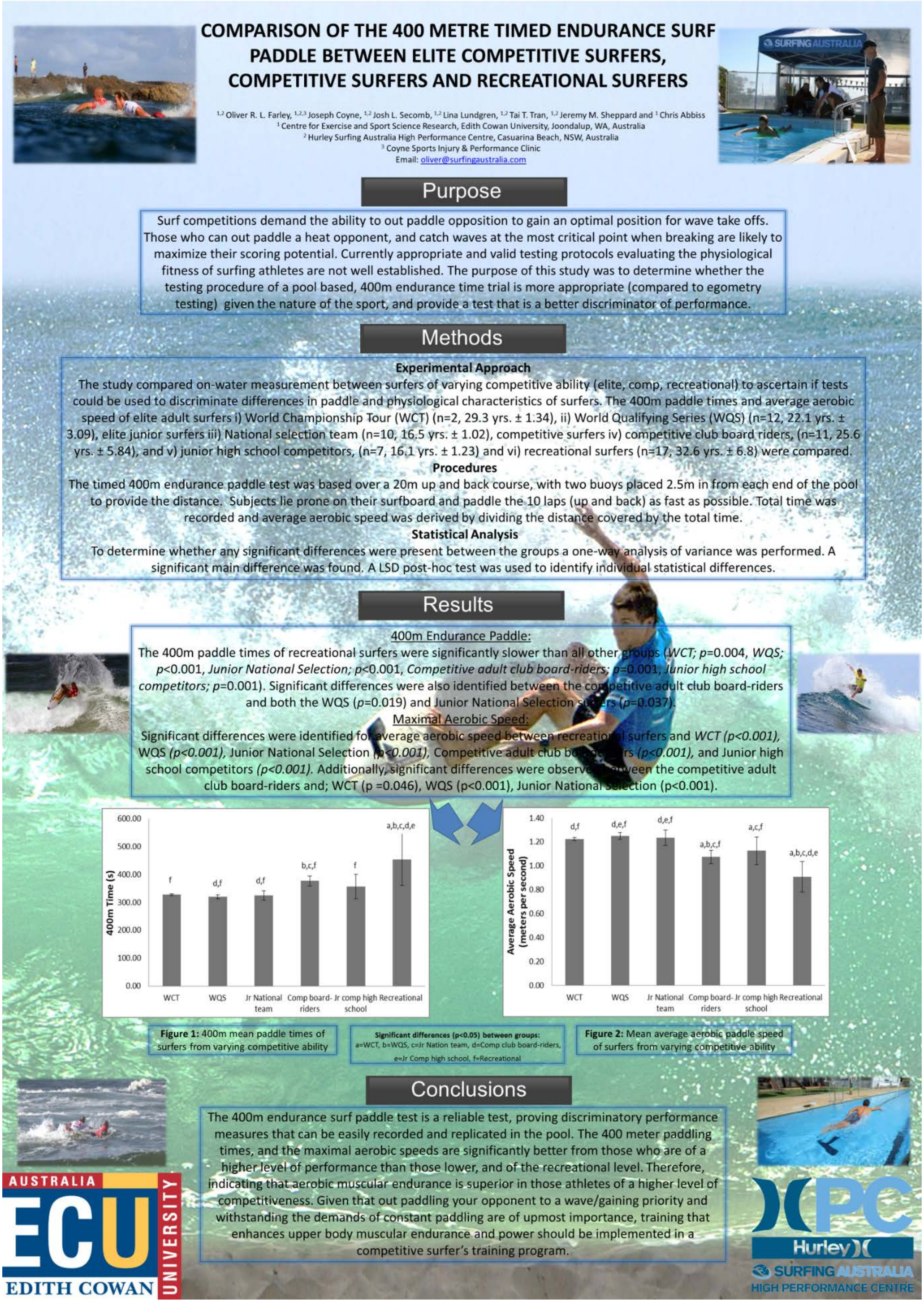
Signed ……………………………………………….
Name……………………………………….……..….... **Date**…………..…

Parent/guardian Signed ……………………………………………..…

Name……………………………………...…………... **Date**………..……

Signed by member of research team ……………………………………………….….

Appendix 6: Conference Poster



Appendix 7: Conference Poster (Study 1)

THE VALIDITY AND INTER-UNIT RELIABILITY OF CUSTOM-MADE SURFTRAX GPS UNITS AND USE DURING SURFING

[1,2]Oliver R. L. Farley, [3]Mark Andrews, [1,2]Josh L. Secomb, [1,2]Lina Lundgren, [1,2]Tai T. Tran, [1]Chris Abbiss and [1,2]Jeremy M. Sheppard
[1]Centre for Exercise and Sport Science Research, School of Exercise and Health Science, Edith Cowan University, Joondalup, WA, Australia
[2]Hurley Surfing Australia High Performance Centre, Casuarina Beach, NSW, Australia
[3]Queensland Academy of Sport, Nathan, QLD, Australia
Email: oliver@surfingaustralia.com

Purpose

The purposes of the study were to: i) gain further understanding of the movement patterns during surfing using custom made GPS units which are designed for surfing (SurfTraX, Gold Coast, Australia), and ii) determine the validity and inter-unit reliability of the these units.

Methods

- **Experimental Approach**

To gain a better understanding of the external loads of surfing, 10 surfers during competition had a GPS unit recording data (10Hz), positioned under their wetsuit on upper vertebrae. To determine validity and inter-unit reliability, nine GPS units were used during three specific tests, with units positioned across and taped down to the upper-back of two subjects. Tests consisted of a 100m sprint (similar to wave speeds), running between points in a 'W' shaped course (replicate bottom and top turns on a wave), and walking around a rugby field, making sharp rotation at each corner (replicate paddling and turns). Validity was determined by comparing GPS distance and actual tape measured. Inter-unit reliability was determined by comparing distance covered, peak velocity, and time to cover distance from 20 (subject one) and 25 (subject two) data sets.

- **Statistical Analysis**

Descriptive statistics were calculated for all variables and reported as mean ± SD (and range). Paired sample t-tests were used for GPS validity by determining the differences between actual test distance and GPS unit recordings, as well as comparisons between all units using SPSS (Version 22.0; Chicago, IL) with statistical significance at $p \leq 0.05$. The inter-unit reliability was determined using Hopkins's reliability spreadsheet to calculate the percentage of typical error of measurement (%TEM), and the intraclass correlation coefficient (ICC). The magnitudes of %TEM used included poor (≥10%), moderate (5–10%), or good (≤5%). Strength of ICC scores was based on Pearson correlation scores system involving trivial (0.0), small (0.1), moderate (0.3), large (0.5), very large (0.7), nearly perfect (0.9), and perfect (1.0). Effect size (*r*) was used (<0.2 = trivial, 0.2–0.6 = small, 0.6–1.2 = moderate, 1.2–2.0 = large, and >2.0 = very large) in determining difference between measured distance and GPS distance.

Results

- **Surfing**

Surfers travelled a total distance (including all movements such as paddling, and wave riding) of 997m (range; 628m – 1678m) per 20 min heat, at an average speed of 16.7 km/h per wave, with peak wave ridings speeds approximately 25.2km/h (19 – 31km/h). The maximal distance covered during a wave was 132m (82m – 180m).

- **GPS Validity**

Validity was determined from 12 sets of data over the courses. No significant difference were reported between actual distance of the 100m sprint (101.1 ± 4.46m, p = .422, t = .834), W course (28.4m) (28.58± 5.65, p = .913, t = .112) and the walk (336m) (334.6 ± 7.80, p = .636, t = -.494). Furthermore, no significant difference were reported between all GPS units measures (100m sprint, p = .987, t = -.017), (W course, p = .100, t = -1.814), (Walk p = .180, t = 1.491). Effect size between actual measures and that of all GPS recordings (n = 45) were r = 0.5 for the walk, r = 0.3 for W run and r = 0.7 for 100m sprint.

- **GPS Inter-unit Reliability**

All inter-unit reliability results are reported in Tables 1 and 2 for the two subjects performing the tests over the two days.

Table 1: Raw data are presented with mean ±SD from subject one using GPS units 1 – 4.
*Set 1 and 2 on day 1; Sets 3 – 5 on day 2

Variable	Set 1	Set 2	Set 3	Set 4	Set 5	ICC	%TEM
Peak Speed (km/h)							
100m	26.5 ± 0.45	29.2 ± 0.45	29.0 ± 0.47	27.5 ± 0.36	29.3 ± 0.52	**0.94**	**0.95**
W run	14.7 ± 0.26	14.3 ± 0.37	13.5 ± 1.22	13.5 ± 1.02	13.9 ± 0.78	**0.90**	**1.85**
Walk (mean)	5.2 ± 0.05		4.7 ± 0.06	4.5 ± 0.06		**1.00**	**0.55**
Distance (m)							
100m	109.2 ± 1.55	115.3± 1.38	99.15 ± 3.66	104.2 ± 5.29	99.8 ± 0.24	**0.71**	**1.60**
W run	32.3 ± 2.51	27.9 ± 0.58	31.35 ± 9.71	26.9 ± 2.14	27.5 ± 1.65	**0.23**	**9.50**
Walk	377.7 ± 2.85		336.4 ± 7.47	332.8 ± 8.80		**0.87**	**0.70**
Time (s)							
100m	16.5 ± 0.30	15.3 ± 0.21	14.0 ± 0.17	14.8 ± 0.10	13.9 ± 0.24	**0.78**	**1.35**
W run	8.5 ± 0.45	8.2 ± 0.32	7.6 ± 1.51	8.6 ± 0.15	8.6 ± 0.25	**0.74**	**6.60**
Walk	235.5 ± 0.58		260.2 ± 0.13	273.3 ± 0.27		**0.98**	**0.10**

Table 2: Raw data are presented with mean ± SD from subject two using GPS units 5 – 9.
*Set 1 and 2 on day 1; Sets 3 – 5 on day 2

Variable	Set 1	Set 2	Set 3	Set 4	Set 5	ICC	%TEM
Peak Speed (km/h)							
100m	28.6 ± 0.22	31.0 ± 0.13	31.6 ± 0.65	29.9 ± 0.59	29.7 ± 0.58	**0.78**	**0.85**
W run	14.3 ± 1.04	14.9 ± 0.96	11.7 ± 0.85	11.8 ± 1.37	12.3 ± 1.21	**0.30**	**4.22**
Walk (mean)	5.1 ± 0.15		4.4 ± 0.65	4.2 ± 0.19		**0.69**	**1.50**
Distance (m)							
100m	110.3 ± 3.26	113.3 ± 1.05	100.2 ± 0.15	106.6 ± 4.27	99.1 ± 1.55	**0.43**	**2.40**
W run	34.3 ± 2.83	32.1 ± 2.87	25.3 ± 0.53	26.4 ± 2.49	26.4 ± 2.49	**0.16**	**6.95**
Walk	366.6 ± 28.74		326.7 ± 19.33	427.4 ± 34.31		**0.92**	**1.80**
Time (s)							
100m	16.1 ± 0.38	15.6 ± 0.10	12.9 ± 0.44	13.9 ± 0.36	13.9 ± 0.36	**0.80**	**2.00**
W run	9.7 ± 0.71	9.3 ± 0.47	8.0 ± 1.35	8.7 ± 0.54	7.9 ± 0.48	**0.81**	**6.15**
Walk	211.5 ± 28.74		254.5 ± 8.24	272.2 ± 1.02		**0.18**	**2.20**

Conclusions

- The validity of the GPS units demonstrated valid measures with no significant differences being reported between measures (Small (≤0.6) and moderate (0.7) effect size (*r*) between 45 GPS recordings do indicate slight difference). The inter-unit reliability revealed good levels of repeatability when measuring the peak speed per test (0.55 – 4.22%). Likewise, distance and times recorded for the 100m sprint and the walk also had good levels of repeatability (0.10 – 2.40%). The 'W' course measures were reported to have moderate levels of repeatability for distance and time (6.15 – 9.50%).
- The application of GPS during surfing has provided valid insights of the sport and is a simple piece of technology to place under the wetsuit to gather important performance data, which is useful in designing training programs and testing protocols. The activities associated with surfing should be interpreted with caution, particularly peak velocities and distance travelled while surfing on a wave, as surfers are often riding horizontally along the wave, and going from the top to the bottom of the wave. GPS units record changes in horizontal direction; therefore wave riding at speed and turning (≥20km/h) are likely to be slightly overestimated, with total distances at low speed (≤10km/h) potentially underestimated.

Appendix 8: Conference Poster (Study 4)

AUSTRALIA ECU EDITH COWAN UNIVERSITY

Tracking 6 Weeks of Training/Surfing Sessions of Adolescent Competitive Surfers: Just what are these young surfers up to?

[1,2]Oliver R. L. Farley, [1,2]Josh L. Secomb, [1,2]Joanna Parsonage, [1,2]Lina Lundgren, [1]Chris Abbiss and [1,2]Jeremy M. Sheppard
[1]Centre for Exercise and Sport Science Research, School of Exercise and Health Science, Edith Cowan University, Joondalup, WA, Australia
[2]Hurley Surfing Australia High Performance Centre, Casuarina Beach, NSW, Australia
Email: oliver@surfingaustralia.com

HPC Hurley SURFING AUSTRALIA HIGH PERFORMANCE CENTRE

Purpose

The assessment of weekly and even monthly surf practice/training hours is vital for understanding the loads these up and coming surfers endure. Such information will help understand what kind of training these athletes are undertaking, how long they are surfing, what they consider training, and also areas that should be improved upon, in terms of specific training. The purpose of this study was to establish surfers' training hours in terms of strength, balance and conditioning hours, as well as surfing hours, coached hours and competition hours. The monitoring of the athletes will provide insights into the weekly surf hours compared to land-based training these athletes do.

Methods

- **Experimental Approach**

The study was a descriptive analysis, whereby eight adolescent surfers were required to report their surfing hours and physical training hours over a six week period. After each training session over a six week period, the participants were asked to report their surfing and training hours for the week by filling in a paper and pen questionnaire twice a week . Specifically, the participants were asked to provide the amount of hours spent free surfing, being coached, competing, strength training, conditioning and balance work. Athletes were questioned about what they did to make sure sections were filled in correctly in terms of the physical activity (i.e. running, skateboarding = conditioning, periodized strength training = strength, gymnastics = balance).

- **Statistical Analysis**

Descriptive statistics were calculated for all variables and reported as mean ± SD. A one-way ANOVA was performed between the surfing variables; free surfing vs coach, coached vs competition, free surfing vs competition, and between the training variables; strength vs conditioning, conditioning vs balance, balance vs strength on the average weekly hours. Data was statistically analysed using statistical analysis package (SPSS, Version 22.0; Chicago, IL), with statistical significance defined as $p \leq 0.05$.

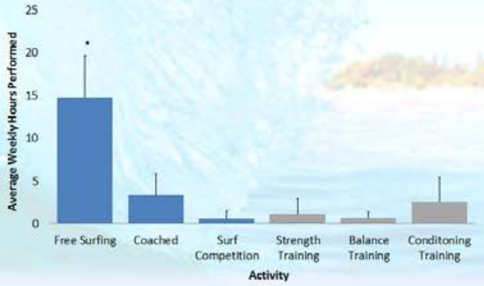
Results

A significant difference was identified between weekly free Surfing hours and competition hours ($p=0.037$), no other significant differences were reported between the surfing variables (Free surfing vs Coached $p=0.751$; Coached vs Competition $p=.523$), or between the training variables (Strength vs Conditioning $p=.553$; Conditioning vs Balance $p=.269$; Balance vs Strength $p=.722$).

Table 1: The average (±SD) hours spent surfing and training per week, over 6 weeks for 8 adolescent surfers

Measure	Week 1 hours	Week 2 hours	Week 3 hours	Week 4 hours	Week 5 hours	Week 6 hours	Average hours
Surfing							
Free Surfing	16.63 ± 7.19	13.00 ± 6.02	15.38 ± 4.78	15.50 ± 3.07	12.75 ± 3.37	15.50 ± 4.11	**14.79 ± 4.86**
Coached	3.81 ± 3.35	2.75 ± 2.60	3.00 ± 2.39	3.44 ± 2.19	3.44 ± 2.19	3.50 ± 2.33	**3.32 ± 2.51**
Competition	0.13 ± 0.35	2.33 ± 3.28	0.25 ± 0.53	0.25 ± 0.71	0.18 ± 0.36	0.24 ± 0.37	**0.56 ± 0.93**
Total surfing hours	**20.56 ± 10.89**	**18.08 ± 11.91**	**18.63 ± 7.70**	**19.19 ± 6.61**	**16.36 ± 5.93**	**19.24 ± 6.81**	**18.68 ± 8.31**
Training							
Strength	0.80 ± 1.14	1.30 ± 2.41	1.18 ± 2.07	1.05 ± 1.75	0.93 ± 1.43	1.30 ± 2.16	**1.09 ± 1.83**
Balance	1.05 ± 0.87	0.36 ± 0.44	0.61 ± 0.70	0.61 ± 0.70	0.74 ± 0.61	0.74 ± 0.66	**0.69 ± 0.67**
Conditioning	2.43 ± 4.04	3.03 ± 3.52	2.65 ± 2.80	2.28 ± 2.16	2.28 ± 2.16	2.44 ± 2.06	**2.58 ± 2.84**
Total training hours	**4.28 ± 5.71**	**4.69 ± 6.37**	**4.44 ± 5.57**	**3.94 ± 4.60**	**3.94 ± 4.60**	**4.48 ± 4.88**	**4.35 ± 5.34**

Figure 1: The average (±SD) weekly hour's adolescent surfers perform free surfing, being coached, competing in surfing competitions, and performing land-based strength, balance and conditioning training



Conclusions

- The typical attitude for surfing athletes in terms of training is to simply surf, thus obtaining the most specific fitness responses, which is clearly demonstrated from the results. Some athletes questioned did not do any form of strength work, nor have a reason to why they should be implementing such an aspect into their weekly training routine. Often skateboarding was mentioned by the males as an activity they would partake in when surf was inadequate, or to have fun with friends. This would provide motor-skill acquisition, balance and conditioning work which would also develop the quadriceps endurance, considering some were skating for an hour at a time.
- From the study it appears that adolescent surfers are implementing on average, 14 hours extra surfing than any form of land-based training, with approximately only 1 hour per week doing any form of strength work. Therefore, such athletes should be looking to increase training hours per week, especially strength work which would aid these athletes in terms of paddle ability though upper-body training [1, 2], turning manoeuvres and landings, through lower-body strength work [3]. The added training may decrease chances of these athletes sustaining an injury through overuse from the amount of surfing performed each week, not to mention poor biomechanical landings/body movements, which if the athletes are not strong enough would likely increase the chances of sustaining an injury [4].

1. Sheppard, J.M., et al., Association between anthropometry and upper-body strength qualities with sprint paddling performance in competitive wave surfers. Journal of Strength and Conditioning Research, 2012. 26(12): p. 3345–3348.
2. Eurich, A.D., et al., Performance differences between sexes in the pop-up phase of surfing. The Journal of Strength & Conditioning Research, 2010. 24(10): p. 2821-2825.
3. Sheppard, J.M., et al., Development of a Comprehensive Performance-Testing Protocol for Competitive Surfers. International journal of sports physiology and performance, 2013. 8: p. 490-495.
4. Lundgren, L., et al., High ankle sprain: the new elite surfing injury?: case report. International SportMed Journal, 2014. 15(4): p. 321-327.