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# Training adaptations in lower-body muscle structure and physical performance capacities of competitive surfing athletes

Josh Secomb  
*Edith Cowan University*

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**TRAINING ADAPTATIONS IN LOWER-BODY MUSCLE  
STRUCTURE AND PHYSICAL PERFORMANCE CAPACITIES OF  
COMPETITIVE SURFING ATHLETES**

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Submitted to

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Sports Science

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## **ABSTRACT**

The overall aim of this thesis was to increase strength and conditioning coaches, and sport scientists' understanding of the lower-body muscle structures related to enhanced lower-body physical capacities, and how to best evoke desirable training-specific adaptations. To address this aim, three successive steps of research were evaluated: (1) analysis of the factors related to increased performance in competitive surfing, (2) relationships between lower-body muscle structures and factors associated with enhanced physical performance, and (3) comparison of the training-specific adaptations evoked from various training methods. Whilst this research specifically focused on competitive surfing athletes, these results may benefit the training practices of athletes from a wide range of sports. The comprehensive conclusion of the research studies in this thesis suggest that competitive surfing is highly reliant on lower-body force producing capabilities, with specific vastus lateralis and lateral gastrocnemius muscle structures significantly related to these lower-body physical performance capacities. Additionally, the separation of strength and, gymnastics and plyometric training may not be best practice for adolescent athletes. However, a short duration combined strength, plyometric and gymnastics training intervention appears to provide a significant stimulus to evoke desirable adaptations in lower-body muscle structure and physical performance capacities for athletes that have limited opportunities for training between major competitions. Therefore, this thesis has provided descriptive, predictive and determinant findings associated with the physical preparation of surfing athletes, and

therefore, provides strength and conditioning coaches, and sport scientists with an enhanced understanding of how best to evoke desirable adaptations in lower-body muscle structure and physical performance capacities.

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2016

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## **DEDICATION**

I wish to dedicate this thesis to my fiancé Dion, son Koen, and baby daughter Arika. You took a chance on following me on this journey three years ago, and I wouldn't have been able to do it without your love, support and understanding. Also to Mum, for your unconditional love and support.

## PREFACE

This thesis comprises eight manuscripts, seven of which are either published or accepted for publication with the eighth currently in review. Of the eight manuscripts, five are full papers (Chapters Two to Five) and three are full conference papers (Chapter Six). The eight manuscripts have been published in five different journals, and are generally presented in this thesis in the format of the particular journal, with the exception of referencing, which has been uniformly formatted. Furthermore, the terms “muscle-tendon complex stiffness” and “eccentric leg stiffness” have been used interchangeably, however, both are calculated from the eccentric component of the countermovement jump. Additionally, the terms “power”, “explosiveness” and “jumping performance” were used interchangeably. The specific terminology utilised in each manuscript was determined by the journal requirements, or reviewer requests, however, these terms refer to the same variables. The publications previously described that comprise this thesis are outlined below.

### **Manuscripts:**

**Secomb, J. L.**, Farley, O. R. L., Lundgren, L., Tran, T. T., King, A., Nimphius, S. and Sheppard, J. M. 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, 2015.

**Secomb, J. L.**, Lundgren, L. E., Farley, O. R. L., Tran, T. T., Nimphius, S. and Sheppard, J. M. Relationships between lower-body muscle structure and lower-body strength,

power and muscle-tendon complex stiffness. *The Journal of Strength and Conditioning Research*. 29(8): 2221-2228, 2015.

**Secomb, J. L.**, Nimphius, S., Farley, O. R. L., Lundgren, L. E., Tran, T. T. and Sheppard, J. M. Relationships between lower-body muscle structure and, lower-body strength, explosiveness and eccentric leg stiffness in adolescent athletes. *Journal of Sports Science and Medicine*. 14: 691-697, 2015.

**Secomb, J. L.**, Nimphius, S., Farley, O. R. L., Lundgren, L. E., Tran, T. T. and Sheppard, J. M. Lower-body muscle structure and jump performance of stronger and weaker surfing athletes. *International Journal of Sports Physiology and Performance*. 11(5): 652-657, 2016.

**Secomb, J. L.**, Farley, O. R. L., Nimphius, S., Lundgren, L. E., Tran, T. T. and Sheppard, J. M. The training-specific adaptations resulting from resistance training, gymnastics and plyometric training, and non-training in adolescent athletes. *International Journal of Sports Science and Coaching*. In Press.

#### **Conference Abstracts:**

**Secomb, J. L.**, Nimphius, S., Lundgren, L. E., Parsonage, J., Farley, O. R. L., Tran, T. T. and Sheppard, J. M. The training-specific adaptations resulting from a short block of combined strength, plyometric and gymnastics training. *Journal of Australian Strength and Conditioning*. 23(6): 83-85, 2015.

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**Secomb, J. L.**, Nimphius, S., Farley, O. R. L., Lundgren, L. E., Tran, T. T., Parsonage, J. and Sheppard, J. M. Three weeks cessation from strength training in adolescent athletes increases lower-body isometric strength. *Journal of Australian Strength and Conditioning*. 23(6): 26-29, 2015.

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## LIST OF ABBREVIATIONS

<b>1-RM</b>	One repetition maximum
<b>1RM</b>	One repetition maximum
<b>90%CI</b>	Ninety percent confidence interval
<b><math>\Theta</math></b>	Angle
<b><math>\Delta L</math></b>	Vertical displacement of the centre of mass
<b>ANCOVA</b>	Analysis of covariance
<b>ANOVA</b>	Analysis of variance
<b><i>B</i></b>	Beta coefficient
<b>cm</b>	Centimetres
<b>CMJ</b>	Countermovement jump
<b>COM</b>	Centre of mass
<b>CV%</b>	Coefficient of variation percent
<b>DDJ</b>	Drop depth jump
<b>DSD</b>	Dynamic strength deficit
<b><i>d</i></b>	<i>Cohen's d</i>
<b>Ecc</b>	Eccentric
<b>ES</b>	Effect size
<b>EUR</b>	Eccentric utilization ratio
<b>FL</b>	Fascicle length
<b><math>F_{peak}</math></b>	Peak ground reaction force
<b><i>g</i></b>	<i>Hedges's g</i>

<b>H</b>	Height
<b>H<sub>ecc</sub></b>	Eccentric centre of mass displacement
<b>Hz</b>	Hertz
<b>ICC</b>	Intraclass correlational coefficient
<b>IMTP</b>	Isometric mid-thigh pull
<b>kg</b>	Kilograms
<b><i>k<sub>leg</sub></i></b>	Eccentric leg stiffness
<b>LG</b>	Lateral gastrocnemius
<b>LLG</b>	Left lateral gastrocnemius
<b>LVL</b>	Left vastus lateralis
<b>m</b>	Metres
<b>m•s<sup>-1</sup></b>	Metres per second
<b>MHz</b>	Megahertz
<b>MTC</b>	Muscle-tendon complex
<b>MTU</b>	Muscle-tendon unit
<b>N</b>	Newtons
<b><i>N</i></b>	Subject number
<b>n</b>	Subject number
<b><i>n</i></b>	Subject number
<b>N•BW<sup>-1</sup></b>	Newtons per kilogram of body weight
<b>N•m<sup>-1</sup></b>	Newtons per meter
<b>PCSA</b>	Physiological cross-sectional area

<b>PF</b>	Peak force
<b>PV</b>	Peak velocity
<b><math>\rho</math></b>	Spearman's rho correlation coefficient
<b><math>p</math></b>	p-value
<b><math>r</math></b>	Correlation coefficient
<b><math>r^2</math></b>	Coefficient of determination
<b>RLG</b>	Right lateral gastrocnemius
<b>rPF</b>	Relative peak force
<b>RVL</b>	Right vastus lateralis
<b>SD</b>	Standard deviation
<b>SJ</b>	Squat jump
<b>SSC</b>	Stretch-shortening cycle
<b><math>V_{ecc}</math></b>	Eccentric peak velocity
<b>VL</b>	Vastus lateralis
<b>WCT</b>	World Championship Tour
<b>y</b>	Years
<b>yrs</b>	Years

# CHAPTER ONE

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Introduction

## **1 INTRODUCTION**

This series of studies involved three essential components used to enhance physical preparation: (1) analysis of the factors related to increased performance in the specific sport, (2) relationships between lower-body muscle structure and factors associated with enhanced physical performance, and (3) comparison of the training-specific adaptations evoked from various training methods. The first component (Chapter Two) involved an analysis of the physical performance capacities related to competitive surfing performance. The second component (Chapters Three and Four) required an analysis of lower-body muscle structures related to the expression of physical performance capacities. The third component (Chapters Five and Six) investigated the adaptations on these lower-body muscle structures and physical performance capacities in response to varying training methods.

### **1.1 Literature Review**

As this thesis is inclusive of eight publications each subsequent chapter consists of an introduction that reviews the existing literature relevant to each topic. As such, the following review of the literature should not be considered an all encompassing review, but rather a brief review to highlight the existing literature to demonstrate the identified gaps in the literature leading to the aforementioned aims of the thesis.

### ***1.1.1 Competitive Requirements of Surfing***

Surfboard riding (surfing) is a popular sport that is performed competitively at both recreational and elite levels. Successful surfing requires a high level of both technical proficiency and physical fitness, of which the latter is utilised to provide propulsion through the water, in order to be correctly positioned to catch the most appropriate waves. This propulsion occurs prior to the surfer standing up, through paddling, and using dynamic balance and lower-body strength and power to remain on the board and perform technical manoeuvres, in the most critical sections of the wave (29, 54, 67).

Competitive surfing requires the athlete to perform against one to three fellow surfers, in 20 to 40 minute heats. Each wave ridden by an athlete in competition is scored out of ten, with the winner determined by the surfer with the greatest two wave total, and hence, the highest total score out of 20 (54, 65). The current judging criteria, as noted in the “World Surf League Rule Book”, states that “*surfers must perform a variety of innovative and progressive manoeuvres, with a high degree of difficulty and commitment*” (54, 65). To be successful in this, surfers must perform major manoeuvres whilst maintaining speed, power, and flow of the surfboard (54). As a result, competitive surfing is scored solely on technical ability and skills on a wave, and as such, it is important to develop an understanding of the factors that underpin a surfer’s ability to perform scoring manoeuvres during wave riding.

### ***1.1.2 Importance of Scoring Manoeuvres in Competitive Surfing***

As noted, the rules of surfing competition state that major manoeuvres are scored more highly if they are innovative and progressive, and performed with a high degree of difficulty (54). Lundgren et al. (59) demonstrated that when compared to waves that do not involve an aerial manoeuvre (manoeuvres performed above the lip of the wave), those containing an aerial manoeuvre achieve significantly greater mean and peak scores during elite competitive events. As a result, aerial manoeuvres are becoming more frequently performed during both surfing training sessions and competitive events. Furthermore, although it has been reported that aerial manoeuvres score more highly than turning manoeuvres in competition, it should be noted that turning manoeuvres are performed with a significantly higher attempt and completion rate, compared to aerial manoeuvres (59). Due to this, it is essential that competitive surfers possess the ability to perform both aerial and turning manoeuvres, with a high level of technical proficiency and consistency, in order to achieve competitive success. Whilst it is apparent that surfers with superior aerial and turning manoeuvre ability would possess an increased capacity for competitive performance, no research to date has investigated the physical capacities, which may be related to the performance of such manoeuvres. Through determining the physical capacities related to scoring manoeuvre performance in competitive surfers, it may be possible to increase competitive scoring potential by undertaking specific training to attain desirable training-specific adaptations.

### ***1.1.3 Lower-Body Muscle Structure***

Previous research has demonstrated that a muscle's force generating capacities are highly influenced by the structural arrangement of the fascicles (8, 27, 28, 60). As muscle structure demonstrates large plasticity, developing a sound knowledge of the mechanical stimuli that create adaptations in the muscle's structure is of great importance (8). Furthermore, understanding the relationships between muscle structure and physical performance can greatly assist strength and conditioning practitioners with the ability to prescribe effective training programs to evoke specific structural changes, as opposed to merely mimicking movement velocities and patterns. Additionally, this will allow practitioners to identify the aspect of performance that may have the greatest immediate window of opportunity for change (27).

The three muscle structure variables that are of most interest to strength and conditioning coaches, and are easily viewable through B-mode ultrasonography include; muscle thickness, pennation angle and fascicle length (46). Muscle thickness refers to the distance between the deep and superficial aponeuroses. Additionally, pennation angle is the angle between the deep aponeurosis and the line the fascicle, with the fascicle length being the total length of the fascicle, from the deep to superficial aponeuroses (28, 71). Previous research has reported a significant correlation between pennation angle and muscle thickness in resistance trained men (46). Conversely, Blazevich et al. (9) indicated that concomitant increases were observed in muscle thickness and fascicle length, with an absence of any change to pennation angle following sprinting and

jumping training. As such, it appears that the mechanism for muscular hypertrophy may be individual or training response specific. Regardless of whether the mechanism for muscular hypertrophy is increased pennation angle or fascicle length this is a desirable training adaptation, as the increase in muscle sub-units in either parallel or series, respectively, allows for increased force production (101).

Whilst it had been established that higher performing 100 m sprinting athletes possess greater fascicle length and less pennation angle (53), Earp et al. (28) identified that better performance in the CMJ is associated with decreased fascicle length and greater pennation of the lower-body musculature. Furthermore, it was also noted that lateral gastrocnemius (LG) muscle structure could predict jumping ability in resistance trained male subjects ( $n=25$ ) (28). Additionally, a significant amount of variance was explained by LG pennation angle and; CMJ height ( $r^2=0.19$ ,  $p=0.02$ ), CMJ relative power ( $r^2=0.42$ ,  $p<0.01$ ), drop depth jump (DDJ) height ( $r^2=0.26$ ,  $p<0.01$ ), and DDJ relative power ( $r^2=0.17$ ,  $p=0.02$ ). It has been suggested that these relationships existed as greater pennation within the muscle not only allows for an increased number of muscle fibres to attach to the tendon within a given physiological cross-sectional area (PCSA), thereby increasing force production, but also as highly pennate muscles will rotate during contractions (8, 9, 27). As a result of this rotation, the fibres are able to shorten at a velocity lower than that experienced by the total muscle, and hence, force generation is increased by altering the force-velocity relationship. During rotation the fibres are also

able to remain at lengths closer to optimum within the length-force relationship, again improving force production during contractions (8, 9).

Furthermore, it has been noted that when negative momentum must be overcome, and during high eccentric loadings, muscles with shorter fascicle lengths and greater pennation are more suitable. This is the result of longer fascicles demonstrating greater instability, and increased pennation allowing for greater passive resistance of non-parallel contractile components, and hence, increased muscular stiffness and greater isometric-like qualities during muscle lengthening (10, 28). This contention is supported by Earp et al. (28) who identified that the difference in jump heights between CMJ and DDJ explains a significant amount of the variance with LG fascicle length ( $r^2=0.26$ ,  $p<0.01$ ), indicating that shorter fascicle lengths are more conducive to an improved ability to withstand high eccentric forces. As successful aerial and turning manoeuvre performance requires the surfer to arrest high forces and land in a controlled state following the manoeuvre, it is apparent that highly-developed lower-body eccentric strength is necessary, and hence, higher performing aerial surfers may possess muscles with shorter fascicle lengths and greater pennation. Although an analysis of aerial manoeuvres indicates similarities to the movement pattern of the CMJ, no research to date has substantiated these assumptions. As such, identification of the lower-body muscle structures that may help to discriminate between higher- and lower-performing aerial surfers is necessary not only due to potentially improving talent identification, but also to

allow practitioners to prescribe training programs that can evoke desirable adaptations in the surfers' lower-body muscle structure.

#### ***1.1.4 Training-Specific Adaptations in Lower-Body Muscle Structure***

Novel research identified the specific muscle structure adaptations that result from both plyometric and resistance training (8, 9, 94). Blazeovich et al. (9) identified that following five weeks of sprint and plyometric training there was a significant decrease in vastus lateralis (VL) pennation angle ( $p < 0.01$ ), and an increase in VL fascicle length ( $p < 0.05$ ) and muscle thickness ( $p < 0.05$ ). However, with the inclusion of lower-body resistance training over the five weeks significant increases were observed in VL fascicle angle ( $p < 0.05$ ) and muscle thickness ( $p < 0.05$ ), whilst no significant change was identified in VL fascicle length (9). Similarly, Blazeovich et al. (8) reported that following ten weeks of resistance training significant increases in VL fascicle angle were observed at both the five week ( $p < 0.05$ ) and ten week ( $p < 0.01$ ) points. Further, an increase in lower-body strength was associated with a concurrent increase in PCSA of the VL (8). As absolute lower-body power has been significantly correlated with LG muscle thickness (28), it appears that resistance training may be appropriate for surfing athletes aiming to improve their scoring manoeuvre performance as it may result in training-specific increases in lower-body pennation angle and muscle thickness (46, 47) that could be beneficial during the turns and landings of aerial manoeuvres. In summary, the research to date indicates that high-force, low-velocity resistance training leads to increases in muscle thickness and pennation angle, with little to no change in fascicle length.

Conversely, low-force, high velocity training evokes adaptations that result in increased fascicle length, decreased pennation, and little to no change in muscle thickness (27).

Whilst the current literature indicates that significant training-specific adaptations in muscle structure can be achieved in a relatively short period of time through resistance training and plyometric methods, no known research to date has compared the adaptations that result from strength only and gymnastics only training, or investigated the adaptations, which result from combined strength, plyometric and gymnastics training methods. Anecdotally, such methods are currently utilised in high performance surfing programs within Australia, whereby athletes perform maximal and submaximal effort lifts in conjunction with plyometric and gymnastics exercises (forward rolls, rotations, and modified mini trampoline activities) within the same training block, as it is proposed to provide greater overall athletic development. The proposed benefit from the inclusion of gymnastics is that it provides the athlete with a controlled environment to practice aerial manoeuvres, unlike the dynamic, unpredictable environment in which surfing is performed. This should greatly assist with the development of aerial awareness, aerial technique, and landing strategies, which will possess positive benefits to skill acquisition and injury prevention. Investigation of the specific muscle structure adaptations achieved from such methods is warranted as this may greatly enhance the prescription of training to high performance surfing athletes, as coaches would possess a more comprehensive understanding of the underlying training-specific adaptations that this combined form of training evokes. This would greatly enhance training prescription for surfing athletes as

coaches would be able to best prescribe the most effective method to provide the required adaptations for their athletes.

### ***1.1.5 Summary and Implications of Literature Review***

Scoring manoeuvres in competitive surfing are the most important aspect of a surfing athlete's performance, as this is the only component that is included in the scoring criteria (54). However, to date no research has investigated the physical performance capacities that may be related to the performance of such manoeuvres. As a result, it is necessary to investigate the potential relationships between scoring manoeuvre performance and physical performance capacities. Identification of such relationships would provide the initial basis of understanding to better physically prepare surfing athletes for competitive performance and success.

The literature to date have reported that significant relationships exist between specific lower-body muscle structures and physical performance capacities, in adult recreational populations (12, 27, 28). Additionally, training-specific adaptations in lower-body physical capacities have typically been associated with concomitant changes in lower-body muscle structure (9, 21, 71). However, as these studies have typically been performed with adult recreational populations, the application of this literature to elite athletes is limited. Furthermore, to our knowledge no research has investigated the relationships to physical performance capacities, or training-specific adaptations of

lower-body muscle structure in adolescent athletes. As a result, research of this nature would be of benefit to the strength and conditioning literature.

## **1.2 Purpose of the Research**

The research studies contained within this thesis were performed with the overall aim of increasing strength and conditioning coaches, and sport scientists understanding of the lower-body muscle structures related to enhanced lower-body physical capacities, and how to best evoke desirable training-specific adaptations. Whilst it is envisioned that the results of this thesis will benefit the training practices of athletes from a wide range of sports, these research studies specifically focused on the applications for competitive surfing athletes. As such, the overall aim of this research was achieved by investigating three specific aims that will be later broken down into multiple research questions. These aims include: *(1) investigating the factors related to increased performance in surfing*, to establish the lower-body physical capacities that were related to enhanced performance of scoring manoeuvres in surfing (Chapter Two). Once these lower-body physical capacities were identified it was necessary to *(2) investigate the relationships between lower-body muscle structures and factors associated with enhanced physical performance*, to understand the specific lower-body muscle structures related to an enhanced expression of these physical capacities in: competitive adult surfing athletes, competitive adolescent surfing athletes (Chapter Three), and between stronger and weaker competitive adult surfing athletes (Chapter Four).

Finally, the results of the aforementioned studies provided a basis of rationale for the training intervention studies and *(3) comparisons of the training-specific adaptations evoked from various training methods*. Specifically, a comparison of the training-specific adaptations in lower-body muscle structure and physical capacities that resulted from strength only, gymnastics and plyometric only, and non-training in competitive adolescent surfing athletes was performed (Chapter Five). The results of this study suggested that separated training methods are not effective for sports that have a limited opportunity for training between major competitions. As a result, the training-specific adaptations resulting from a short block of combined strength, plyometric and gymnastics training in elite adult surfing athletes were also assessed (Chapter Six-Part One). To improve our understanding of how best to evoke desirable adaptations within an adolescent athletic population, the effect that initial lower-body strength had on adolescent surfing athletes' response to gymnastics and plyometric training was investigated (Chapter Six-Part Two). Finally, the effect of a three week cessation from strength training on training-specific adaptations was analysed to determine whether adolescent surfing athletes experienced a delayed onset of adaptations in lower-body strength or muscle structure (Chapter Six-Part Three).

### **1.3 Significance of the Research**

Competitive surfing is an ever increasingly popular sport, which consists of numerous professional athletes striving for excellence. Due to this, understanding how best to maximize physical preparation for this sport is of utmost importance. However, to

date only limited research has investigated the physical capacities related to enhanced surfing performance, with these studies having focused on upper-body qualities and its' relationships to sprint paddling. As such, it was necessary for the present research to be performed on the relationships between lower-body physical capacities and competitive surfing performance. This will greatly benefit the physical preparation of competitive surfing athletes, through identifying the lower-body physical capacities related to enhanced performance of scoring manoeuvres in competition. Specifically, these results should allow strength and conditioning coaches, and sport scientists to make better informed decisions regarding how best to evoke desirable adaptations in lower-body muscle structure and physical performance capacities, for a range of athletes.

#### **1.4 Research Questions and Hypotheses**

1. Are any lower-body physical performance capacities related to a greater ability to perform scoring manoeuvres in surfing? (Chapter Two)

**Hypothesis:** There will be significant associations identified between lower-body physical performance capacities and the performance of scoring manoeuvres in surfing.

2. Are there significant relationships between lower-body muscle structures and physical performance capacities in both adult and adolescent athletes? (Chapter Three)

**Hypothesis:** Significant associations will exist between lower-body muscle structures and physical performance capacities, however, these will likely differ

between adult and adolescent athletes.

3. What are the lower-body muscle structure and physical performance capacities differences between stronger and weaker surfing athletes? (Chapter Four)

**Hypothesis:** Stronger surfing athletes will possess more desirable lower-body muscle structures and increased physical performance capacities. This may include greater thickness of the lower-body musculature in the stronger athletes.

4. Do meaningful training-specific adaptations in lower-body muscle structure and physical performance capacities, result from a short block of combined strength, plyometric and gymnastics training? (Chapter Five)

**Hypothesis:** Meaningful training-specific adaptations in lower-body muscle structure and physical performance capacities will result from a short block of combined strength, plyometric and gymnastics training. This may be increased force producing capabilities, jumping performance, and associated muscle structures.

5. Do different training-specific adaptations in lower-body muscle structure and physical performance capacities, result from separated resistance, gymnastics and plyometric, and non-training interventions? (Chapter Six-Part One)

**Hypothesis:** Different training-specific adaptations in lower-body muscle structure and physical performance capacities result from strength only, combined gymnastics and plyometric only, and non-training interventions. Specifically, it may be that resistance only training increases force producing capabilities, with associated increases in muscle structures related to these physical capacities.

Conversely, gymnastics and plyometric training may result in increases in jumping performance and the associated muscles structures.

6. Does starting lower-body strength influence the training-specific adaptations in jumping performance resulting from a combined gymnastics and plyometric intervention, in adolescent surfing athletes? (Chapter Six-Part Two)

**Hypothesis:** The adolescent surfing athletes' starting lower-body strength will influence the training-specific adaptations in jumping performance that result from a combined gymnastics and plyometric intervention.

7. Does delayed onset of lower-body muscle structure and strength occur in adolescent surfing athletes, following cessation from strength training? (Chapter Six-Part Three)

**Hypothesis:** There may be a delayed onset of lower-body muscle structure and strength changes that occur following cessation from strength training, in the adolescent surfing athletes.

## CHAPTER TWO

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Associations Between the Performance of Scoring  
Manoeuvres and Lower-Body Strength and Power in Elite  
Surfers.

Citation for this Chapter:

Secomb, J. L., Farley, O. R. L., Lundgren, L., Tran, T. T., King, A., Nimphius, S. and Sheppard, J. M. 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, 2015.

## CHAPTER THREE

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A) Relationships Between Lower-Body Muscle Structure and Lower-Body Strength, Power and Muscle-Tendon Complex Stiffness

B) Relationships Between Lower-Body Muscle Structure and, Lower-Body Strength, Explosiveness and Eccentric Leg Stiffness in Adolescent Athletes

Citations for this Chapter:

Secomb, J. L., Lundgren, L. E., Farley, O. R. L., Tran, T. T., Nimphius, S. and Sheppard, J. M. Relationships between lower-body muscle structure and lower-body strength, power and muscle-tendon complex stiffness. *The Journal of Strength and Conditioning Research*. 29(8): 2221-2228, 2015.

Secomb, J. L., Nimphius, S., Farley, O. R. L., Lundgren, L. E., Tran, T. T. and Sheppard, J. M. Relationships between lower-body muscle structure and, lower-body strength, explosiveness and eccentric leg stiffness in adolescent athletes. *Journal of Sports Science and Medicine*. 14: 691-697, 2015.

## CHAPTER FOUR

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### Lower-Body Muscle Structure and Jump Performance of Stronger and Weaker Surfing Athletes

Citation for this Chapter:

Secomb, J. L., Nimphius, S., Farley, O. R. L., Lundgren, L. E., Tran, T. T. and Sheppard, J. M. Lower-body muscle structure and jump performance of stronger and weaker surfing athletes. *International Journal of Sports Physiology and Performance*. 11(5): 652-657, 2016.

## CHAPTER FIVE

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### The Training-Specific Adaptations Resulting from Strength Training, Gymnastics and Plyometric Training, and Non-Training in Adolescent Athletes

Citation for this Chapter:

Secomb, J. L., Farley, O. R. L., Nimphius, S., Lundgren, L. E., Tran, T. T. and Sheppard, J. M. The training-specific adaptations resulting from resistance training, gymnastics and plyometric training, and non-training in adolescent athletes. *International Journal of Sports Science and Coaching*. In Press.

## CHAPTER SIX

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### Conference Abstracts

#### Citations for this Chapter:

Secomb, J. L., Nimphius, S., Lundgren, L. E., Parsonage, J., Farley, O. R. L., Tran, T. T. and Sheppard, J. M. The training-specific adaptations resulting from a short block of combined strength, plyometric and gymnastics training. *Journal of Australian Strength and Conditioning*. 23(6): 83-85, 2015.

Secomb, J. L., Farley, O. R. L., Lundgren, L. E., Tran, T. T., Nimphius, S. and Sheppard, J. M. The effect of initial lower-body strength on the training-specific adaptations resulting from combined plyometric and gymnastics training. *Journal of Australian Strength and Conditioning*. 22(5): 61-64, 2014.

Secomb, J. L., Nimphius, S., Farley, O. R. L., Lundgren, L. E., Tran, T. T., Parsonage, J. and Sheppard, J. M. Three weeks cessation from strength training in adolescent athletes increases lower-body isometric strength. *Journal of Australian Strength and Conditioning*. 23(6): 26-29, 2015.

# CHAPTER SEVEN

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Conclusions

## **7 CONCLUSIONS**

### **7.1 Lower-Body Physical Capacities Related to Surfing Performance**

Competitive surfing is a sport that is scored solely on the performance of technical manoeuvres during wave riding (54). Due to this, the results in Chapter Two indicating that significant associations were present between turning manoeuvre performance and lower-body dynamic and isometric strength will greatly benefit the physical preparation of surfing athletes, for competitive performance and success (82). These results provide the first evidence that highly developed lower-body physical capacities are associated with competitive surfing performance, and as a result, strength and conditioning coaches working with such athletes will now have an increased understanding of the physical capacities that should be targeted within training. Specifically, lower-body body isometric and dynamic strength, as well as jumping ability should be a major focus in the training programs of competitive surfers. Furthermore, these results provided the basis of rationale for the subsequent studies, which investigated the relationships of these physical capacities to lower-body muscle structure, as well as the training-specific adaptations of these capacities that resulted from a variety of training modalities.

### **7.2 Lower-Body Muscle Structure**

Significant relationships were identified between specific lower-body muscle structures and lower-body strength and jumping performance in the competitive elite

adult and adolescent surfing athletes in Chapters Three A and Three B (81, 84, 85). Specifically, within the elite adult male surfing athletes significant relationships were determined between VL thickness and LG pennation angle, and; PF in the CMJ, SJ and IMTP, as well as CMJ and SJ jump height (84). Additionally, eccentric leg stiffness demonstrated significant relationships with the DSD ratio, and CMJ PF and jump height (84). Similarly, competitive adolescent surfing athletes exhibited significant relationships between VL and LG thickness, and VL pennation, and; CMJ, SJ and IMTP PF (85). However, in the adolescent athletes eccentric leg stiffness was significantly related to VL and LG thickness, and IMTP PF (85). Together, these studies suggest that although there were some differences in the specific lower-body muscle structures related to enhanced CMJ, SJ and IMTP performance between adult and adolescent surfing athletes, ultimately increased thickness of the lower-body musculature is related to greater isometric and dynamic force producing capabilities. Furthermore, it appears that in adult surfing athletes, eccentric leg stiffness is a quality that is significantly related to an athlete's ability to produce force in a dynamic movement, relative to their maximal isometric lower-body strength. Conversely, in adolescent athletes eccentric leg stiffness was related to their lower-body strength and muscle thickness, which is more indicative of reduced compliance, and therefore, more resistance to deformation during an eccentric muscle action.

Although the aforementioned studies identified significant relationships between specific lower-body muscle structures and CMJ, SJ, IMTP performance, these studies

were correlational designs (84, 85), which may have masked the importance of some variables, due to the assumption of linear relationships. Due to this, the comparative study (Chapter Four) was necessary to provide further evidence, as to the relationships between muscle structure and physical performance capacities. Therefore, the results suggesting that a stronger group of elite adult male surfing athletes possessed greater VL and LG thickness, compared to a weaker group, further supported the previous studies suggesting that increased thickness of the lower-body musculature was related to enhanced lower-body force producing capabilities (81). Additionally, this study also identified that the stronger group of athletes demonstrated significantly greater eccentric peak velocity and vertical displacement of the COM, during the eccentric phase of a CMJ (81). Together, these results suggest that the stronger athletes exhibited greater thickness of the lower-body musculature, which was also related to enhanced jumping performance, specifically, increased utilisation of the eccentric phase of a CMJ.

### **7.3 Training-Specific Adaptations**

Whilst extensive research had reported that specific, varying adaptations typically occur in response to strength and plyometric training, in adolescent athletes, there was a paucity of research directly comparing these modalities within the same participants (14, 15, 57). As such, the results of the training study (Chapter Five) provided novel information regarding the training-specific adaptations. Specifically, it was identified that strength only training resulted in large magnitude significant increases in IMTP rPF and VL FL, with gymnastics and plyometric only training evoking significant increases in VL

FL, LG thickness and eccentric leg stiffness, and a significant decrease in VL pennation angle.

Together these results suggested that the strength only training provided a stimulus to evoke significant increases in force producing capabilities, likely due to the increase in VL FL, but also possibly due to neuromuscular factors. Conversely, the gymnastics and plyometric only training resulted in significantly greater muscle structure changes and inherent muscle qualities, which was likely due to the inclusion of high velocity eccentric movements, in the adolescent athletes. Furthermore, it was also identified that the non-training group did not experience any significant training-specific adaptations. This suggests that adolescent surfing athletes should be performing appropriately periodised training in order to maximise their athletic potential, and to set a sound foundation of physical preparedness for their transition into open age surfing competitions. Additionally, the results from Chapter Six-Part Two and Three provide some considerations for the training prescription and testing of adolescents. Specifically, if increases in jumping performance and dynamic strength are desired, it may be that the adolescent athlete should achieve a minimum threshold of lower-body isometric strength (i.e.  $>3.0N \cdot BW^{-1}$ ) (83). Furthermore, when assessing adolescent athletes training-specific adaptations following a period of training it may be that a longer time period (one to three weeks) is provided between the cessation of training and testing, as opposed to the typical 48-72 hours, in order to assess the true magnitude of change due to a lag effect or time to “transfer the training” (70).

The results of Chapter Five highlighted that the separation of training modalities may not be the most appropriate periodisation method for surfing, as there are typically only two to six weeks between major competitions. As such, the training study presented in Chapter Six-Part One may represent one of the most appropriate periodisation method for surfing. This study identified that following a short six week combined strength, plyometric and gymnastics intervention, the elite male surfing athletes achieved large magnitude very likely increases in VL thickness, IMTP PF and rPF, moderate magnitude likely increases in eccentric peak velocity and eccentric COM displacement, and a small magnitude likely increase in LG thickness. Together, these results indicate that likely training-specific adaptations in muscle structure and physical performance capacities can be achieved in a short period of this combined method. Additionally, as likely concomitant increases were present in VL and LG thickness, IMTP PF and rPF, and eccentric peak velocity and COM displacement, it appears that the increases in lower-body musculature thickness and, lower-body isometric strength and the ability to utilise the eccentric component of the CMJ are determinant of one another, expanding upon the previous correlational research.

#### **7.4 Practical Applications From This Thesis**

As a result of the findings observed within this thesis, there are a number of practical applications that may be of use to strength and conditioning coaches and sport scientists:

1. When assessing an athlete, consider including a measure of lower-body musculature thickness. In combination with lower-body strength and jumping assessment this will allow the practitioner to determine whether muscle thickness is a limiting factor for physical performance. For example, if an athlete has poor lower-body strength and a lack of lower-body muscle thickness, the prescription of training focussed on hypertrophy may be warranted. Conversely, if the athlete has poor lower-body strength but high muscle thickness, then training focused on greater neural adaptations associated with rate of force development and maximal force production as a recommended strategy.
2. Prescription of “hypertrophy” range repetitions (eight to 12 repetitions per set) when an athlete commences resistance training. The benefits of this is not only increased lower-body musculature thickness, but also an enhanced opportunity to practice the technique of the prescribed exercise to increase technical competency.
3. Whilst the adolescent athletes only achieved increases in jumping performance when they demonstrated a reasonable level of strength, it is suggested that all adolescent athletes perform plyometric and gymnastics exercises. Although the stronger athletes will likely achieve the greatest adaptations in jumping performance, the weaker athletes should still perform these exercises as they will have the opportunity to practice the technique required for successful SSC performance.

4. When working with sports that have short preparation periods between major competitions (i.e. surfing, golf, tennis) combined training methods appear to be the most effective for training prescription, as opposed to block periodisation.
5. When assessing the training-specific adaptations that have resulted from training in adolescent athletes, it may be necessary to test the athletes following a cessation of training, in order to ensure that the actual adaptations have been realised.

### **7.5 Directions for Future Research**

1. Significant associations were identified between turning manoeuvre performance and, lower-body isometric and dynamic strength, and jumping performance (Chapter Two). Additionally, significant training-specific increases were observed in these physical performance capacities in both competitive adult and adolescent surfing athletes (Chapter Five and Six-Part One). Whilst these results provide useful information, it is necessary to investigate whether increases in lower-body isometric and dynamic strength, and jumping performance are transferred to increases in turning manoeuvre performance.
2. Although the training-specific adaptations in lower-body muscle structure, and strength and jumping performance are presented for both separated (Chapter

Five) and combined (Chapter Six-Part One) methods, it is important to highlight that these were performed with adolescents and adults, respectively. As such, it is necessary to compare both separated and combined methods within the same cohorts. Future research should aim to determine whether separated or combined methods are more advantageous for both adolescent and adult competitive surfing athletes.

3. The studies within this thesis highlighted the importance of lower-body extensor thickness for the expression of strength and jumping performance. However, to our knowledge no previous research has investigated whether lower-body flexor thickness, in particular the hamstrings, is related to the ability to produce strength and jumping performance. Understanding what role the muscle structure of the hamstrings has on these capacities may further benefit our knowledge of the relationships between lower-body muscle structure and lower-body strength and jumping performance.

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## APPENDICES

### APPENDIX A - ETHICS APPROVAL

25 September 2013

Mr Josh Secomb  
4/282 Marine Parade  
KINGSCLIFF NSW 2487

Dear Mr Secomb,

I am pleased to write on behalf of the Research Students and Scholarships Committee who have approved your PhD research proposal: **A series of studies on the physical factors and lower-body muscle architecture related to aerial performance in surfing.** I also wish to confirm that your proposal complies with the provisions contained in the University's policy for the conduct of ethical research, and your application for ethics has been approved. Your ethics approval number is **10228** and the period of approval is **24 September 2013 to 31 December 2015**

Approval is given for your supervisory team to consist of:

Principal Supervisor: Dr Jeremy Sheppard- ECU  
Associate Supervisor: Dr Sophia Nimphius – ECU

I would like to take this opportunity to offer you our best wishes for your research and the development of your thesis.

Yours sincerely

Patricia Brown  
Senior Student Progress Officer  
Research Assessments – SSC

## APPENDIX B - PARTICIPANT INFORMATION SHEETS

Mr Josh Secomb

Strength and Conditioning Scholar/PhD Candidate at Edith Cowan University

School of Exercise and Health Sciences

Faculty of Computing, Health and Science

Hurley Surfing Australia High Performance Centre

7 Barclay Dr, Mainwaring Precinct, Casuarina, 2487, NSW

0402446256

[josh@surfingaustralia.com](mailto:josh@surfingaustralia.com)

### **Information Statement for the Research Project:**

#### **The physical and muscle architectural differences between higher- and lower-performing aerial surfers**

Document Version 1; dated 7/08/2016

You are invited to participate in the research project being conducted by Mr Josh Secomb, Dr. Jeremy Sheppard, and Dr. Sophia Nimphius from the School of Exercise and Health Sciences of Edith Cowan University. Josh Secomb has completed a Bachelor of Exercise and Sports Science (Honours) and is now undertaking a Doctor of Philosophy in Exercise and Sport Science. Josh and Dr Sheppard are based at the Hurley Surfing Australia High Performance Centre, and Dr Nimphius is based at Edith Cowan University. The proposed testing will occur at the Hurley Surfing Australia High Performance Centre.

#### ***Why is the research being done?***

To identify the physical performance and lower-body muscle architectural differences between higher- and lower-performing aerial surfers. Aerial manoeuvres are becoming more frequently performed during both surfing training sessions and competitive events. Whilst it is apparent that surfers with superior aerial ability would possess an increased capacity for competitive performance, no research to date has investigated the physical capacities, which may be related to the performance of such manoeuvres. Through determining the physical capacities related to aerial manoeuvre performance in competitive surfers, it may be possible to increase competitive scoring potential by undertaking specific training to attain desirable training-specific adaptations.

#### ***Who can participate in the research?***

We are seeking any member of the surfing community, with experience in competitive surfing and the ability to perform aerial manoeuvres, to express a desire to participate in the proposed study. To be able to participate you must be aged between 18-35 years of age and will be required to be free of any medical conditions that may identify you to be at higher risk of injury or discomfort during the activities. Participants should have no pre-existing medical issues that may be worsened as a result of completing the research project. Participants will be required to be actively competing at a minimum of state level competition.

***What choice do you have?***

Participation in this research is entirely your choice. Only those people who provide informed consent will be included in the project. Whether or not you decide to participate, your decision will not disadvantage you. If you do decide to participate, you may withdraw from the project at any time without giving a reason and have the option of withdrawing any data that identifies you.

***What would you be asked to do?***

If you agree to participate, you will be asked to complete the following questionnaires and testing protocols:

***Pre Exercise Health Screening Questionnaire***

The purpose of the Pre-Exercise Health Screening Questionnaire is to ensure you do not have any current or previous health issues that may place you at a risk of injury during the testing.

***Exercise Testing***

Participation in the proposed study will require you to complete a series of physical tests at the Hurley Surfing Australia High Performance Centre. In the weeks prior to, and following each training intervention, you will complete a restricted anthropometric assessment (height, weight and sum of seven skinfolds) and a battery of physical tests during a single session. Physical tests include; countermovement jump (CMJ), drop depth jump (DDJ), static jump (SJ), isometric mid-thigh pull (IMTP), and the drop and stick. Prior to testing, your muscle and tendon structure will be assessed using ultrasonography. The ultrasonography results will allow for the pennation angle, muscle fibre length, and muscle thickness of vastus lateralis (VL) and lateral gastrocnemius (LG) to be assessed, as well as the length of the Achilles tendon (AT) relative to the muscle-tendon unit. Additionally, the National Coaching Director for Surfing Australia, and the ASP Australasian Head Judge will rank each surfer from one to fifty for their aerial manoeuvre ability, based on recent competitive observation.

***How much time will it take?***

The data collection session will last a total of approximately two hours to allow for health screening, ultrasonography, and physical testing. You will be required to provide the researchers with three available times that you can participate during the testing period. Based on these times, you will be randomly allocated to a time slot that the researchers will inform you of.

***What are the risks and benefits of participating?***

Although unlikely, the study presents some risk to participants in the form of muscle soreness from the training and risk of injury during surfing activity. All exercise testing is performed in a controlled environment and will be stopped by the researcher if deemed

dangerous. As a risk of physical injury may still exist, the researchers will ensure that you have completed a warm-up to minimise the risk of a musculoskeletal injury, and you are familiarised with all tests prior to completing the testing.

As a result of participating in the study, you will receive several benefits. You will undergo physical testing, to assess lower-body strength and power, which will be explained in detailed by the researchers. Following the study, you will also receive a report detailing the findings of the study and arising benefits. This report will provide each participant with their results on each physical test, which measure surfing-specific performance. These results can be used by the participants to assess their surfing-specific fitness, and identify how to improve their performance.

***How will your privacy be protected?***

The confidentiality of this study is assured. Under no circumstances will any names appear on publications associated with this research. The individual results will be provided to you in verbal and written form with no one else being given the results unless you request it. Hard copies of results will be stored in a locked filing cabinet along with backed up data stored securely in the filing cabinet. All video footage will be stored digitally on a secure university computer and network drive, and will be protected by password. The researchers are the only personnel who have access to the data. Your confidentiality will be ensured by replacing your name with a numerical code. The data will be retained for a minimum of five (5) years, at the Hurley Surfing Australia High Performance Centre.

***How will the information collected be used?***

Data will be presented in scientific journals and conferences following the conclusion of the project. All presentation and use of data will be as group and descriptive measures, not individual responses.

***What do you need to do to participate?***

Please read this Information Statement and be sure you understand its contents before you consent to participate. If there is anything you do not understand, or you have questions, contact the researcher.

If you would like to participate, please email the chief investigator on the details below. You will then be required to complete a pre-exercise health-screening questionnaire and consent form prior to participation.

If you are a suitable participant for this study, you will be informed of this upon completion of the pre-exercise health-screening questionnaire. If the pre-exercise health

screen has identified any medical issues, you will be required to seek a medical clearance before being included in the study.

***Further information***

If you would like further information please contact Josh Secomb for further information regarding the study.

Josh Secomb  
Phone: (02) 6671 0000  
Mobile: 0402 446 256  
Email: [josh@surfingaustralia.com](mailto:josh@surfingaustralia.com)

Thank you for considering this invitation.

A handwritten signature in black ink, appearing to read 'J. Secomb', with a stylized flourish at the end.

Josh Secomb

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  
Edith Cowan University  
270 Joondalup Drive  
JOONDALUP WA 6027  
Phone: (08) 6304 2170  
Email: [research.ethics@ecu.edu.au](mailto:research.ethics@ecu.edu.au)

Mr Josh Secomb  
Strength and Conditioning Scholar/PhD Candidate at Edith Cowan University  
School of Exercise and Health Sciences  
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Hurley Surfing Australia High Performance Centre  
7 Barclay Dr, Mainwaring Precinct, Casuarina, 2487, NSW  
0402446256  
[josh@surfingaustralia.com](mailto:josh@surfingaustralia.com)

### **Information Statement for the Research Project:**

**A comparison of the training-specific adaptations of physical capacities and lower-body muscle structure evoked from strength only and gymnastics only training, and the transfer of adaptations to the change in aerial performance**

Document Version 1; dated 7/08/2016

You are invited to participate in the research project being conducted by Mr Josh Secomb, Dr. Jeremy Sheppard, and Dr. Sophia Nimphius from the School of Exercise and Health Sciences of Edith Cowan University. Josh Secomb has completed a Bachelor of Exercise and Sports Science (Honours) and is now undertaking a Doctor of Philosophy in Exercise and Sport Science. Josh and Dr Sheppard are based at the Hurley Surfing Australia High Performance Centre, and Dr Nimphius is based at Edith Cowan University. The proposed testing will occur at the Hurley Surfing Australia High Performance Centre.

#### ***Why is the research being done?***

To compare the training-specific changes in physical capacities and lower-body muscle structure that are evoked from a strength training only and a gymnastics training only intervention. Additionally, we aim to calculate whether the training-specific adaptations in physical performance and muscle structure are associated with improved aerial manoeuvre performance in competitive surfers. Aerial manoeuvres are becoming more frequently performed during both surfing training sessions and competitive events. Whilst it is apparent that surfers with superior aerial ability would possess an increased capacity for competitive performance, no research to date has investigated the physical capacities, which may be related to the performance of such manoeuvres. Through comparing the training-specific adaptations resulting from strength only and gymnastics only training, it may be possible to increase competitive scoring potential by undertaking specific training to attain desirable training-specific adaptations.

#### ***Who can participate in the research?***

We are seeking any member of the surfing community, with experience in competitive surfing and the ability to perform aerial manoeuvres, to express a desire to participate in the proposed study. To be able to participate you must be aged between 18-35 years of age and will be required to be free of any medical conditions that may identify you to be at higher risk of injury or discomfort during the activities. Participants should have no pre-existing medical issues that may be worsened as a result of completing the research

project. Participants will be required to be actively competing at a minimum of state level competition.

***What choice do you have?***

Participation in this research is entirely your choice. Only those people who provide informed consent will be included in the project. Whether or not you decide to participate, your decision will not disadvantage you. If you do decide to participate, you may withdraw from the project at any time without giving a reason and have the option of withdrawing any data that identifies you.

***What would you be asked to do?***

If you agree to participate, you will be asked to complete the following questionnaires, and training and testing protocols:

*Pre Exercise Health Screening Questionnaire*

The purpose of the Pre-Exercise Health Screening Questionnaire is to ensure you do not have any current or previous health issues that may place you at a risk of injury during the testing.

*Training*

Each participant will be initially randomly allocated to either a strength only, or a gymnastics only training group. You will be required to perform two days of training per week, for six weeks. A three week break will occur prior to the training intervention crossover, with the second block of training also performed for two days per week, for six weeks.

*Exercise Testing*

Participation in the proposed study will require you to complete a series of physical tests at the Hurley Surfing Australia High Performance Centre. In the weeks prior to, and following each training intervention, you will complete a restricted anthropometric assessment (height, weight and sum of seven skinfolds) and a battery of physical tests during a single session. Physical tests include; countermovement jump (CMJ), drop depth jump (DDJ), static jump (SJ), isometric mid-thigh pull (IMTP), and the drop and stick. Prior to testing, your muscle and tendon structure will be assessed using ultrasonography. The ultrasonography results will allow for the pennation angle, muscle fibre length, and muscle thickness of vastus lateralis (VL) and lateral gastrocnemius (LG) to be assessed, as well as the length of the Achilles tendon (AT) relative to the muscle-tendon unit.

*Video Recording of Aerial Manoeuvre Performance*

During the weeks both prior to and immediately following each six weeks of training, you will have video-recordings taken of your aerial manoeuvre performance during four one-hour surfing sessions.

***How much time will it take?***

Participants will be required for a total of 17 weeks, for two days each week.

***What are the risks and benefits of participating?***

Although unlikely, the study presents some risk to participants in the form of muscle soreness from the training and risk of injury during surfing activity. All training, exercise testing, and surfing is performed in a controlled environment and will be stopped by the researcher if deemed dangerous. As a risk of physical injury may still exist, the researchers will ensure that; surf conditions are suitable based on advice from the surf lifeguards, you have completed a warm-up to minimise the risk of a musculoskeletal injury, and you are familiarised with all training exercises and tests prior to completing the testing.

As a result of participating in the study, you will receive several benefits. You will undergo physical testing, to assess lower-body strength and power, which will be explained in detailed by the researchers and used to individualise your training programs. From the training it is proposed that each participant should gain a significant increase in fitness. Following the study, you will also receive a report detailing the findings of the study and arising benefits. This report will provide each participant with their final results on each physical test, which measure surfing-specific performance. These results can be used by the participants to assess their surfing-specific fitness, and identify how to further improve their performance.

***How will your privacy be protected?***

The confidentiality of this study is assured. Under no circumstances will any names appear on publications associated with this research. The individual results will be provided to you in verbal and written form with no one else being given the results unless you request it. Hard copies of results will be stored in a locked filing cabinet along with backed up data stored securely in the filing cabinet. All video footage will be stored digitally on a secure university computer and network drive, and will be protected by password. The researchers are the only personnel who have access to the data. Your confidentiality will be ensured by replacing your name with a numerical code. The data will be retained for a minimum of five (5) years, at the Hurley Surfing Australia High Performance Centre.

***How will the information collected be used?***

Data will be presented in scientific journals and conferences following the conclusion of the project. All presentation and use of data will be as group and descriptive measures, not individual responses.

***What do you need to do to participate?***

Please read this Information Statement and be sure you understand its contents before you consent to participate. If there is anything you do not understand, or you have questions, contact the researcher.

If you would like to participate, please email the chief investigator on the details below. You will then be required to complete a pre-exercise health-screening questionnaire and consent form prior to participation.

If you are a suitable participant for this study, you will be informed of this upon completion of the pre-exercise health-screening questionnaire. If the pre-exercise health screen has identified any medical issues, you will be required to seek a medical clearance before being included in the study.

***Further information***

If you would like further information please contact Josh Secomb for further information regarding the study.

Josh Secomb  
Phone: (02) 6671 0000  
Mobile: 0402 446 256  
Email: [josh@surfingaustralia.com](mailto:josh@surfingaustralia.com)

Thank you for considering this invitation.



Josh Secomb

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  
Edith Cowan University  
270 Joondalup Drive  
JOONDALUP WA 6027  
Phone: (08) 6304 2170  
Email: [research.ethics@ecu.edu.au](mailto:research.ethics@ecu.edu.au)

Mr Josh Secomb  
Strength and Conditioning Scholar/PhD Candidate at Edith Cowan University  
School of Exercise and Health Sciences  
Faculty of Computing, Health and Science  
Hurley Surfing Australia High Performance Centre  
7 Barclay Dr, Mainwaring Precinct, Casuarina, 2487, NSW  
0402446256  
[josh@surfingaustralia.com](mailto:josh@surfingaustralia.com)

### **Information Statement for the Research Project:**

**The training-specific adaptations of physical capacities and lower-body muscle structure evoked from a combined strength and gymnastics training intervention, and the transfer of adaptations to the change in aerial performance**

Document Version 1; dated 7/08/2016

You are invited to participate in the research project being conducted by Mr Josh Secomb, Dr. Jeremy Sheppard, and Dr. Sophia Nimphius from the School of Exercise and Health Sciences of Edith Cowan University. Josh Secomb has completed a Bachelor of Exercise and Sports Science (Honours) and is now undertaking a Doctor of Philosophy in Exercise and Sport Science. Josh and Dr Sheppard are based at the Hurley Surfing Australia High Performance Centre, and Dr Nimphius is based at Edith Cowan University. The proposed testing will occur at the Hurley Surfing Australia High Performance Centre and surrounding beaches.

#### ***Why is the research being done?***

To determine the training-specific changes in physical capacities and lower-body muscle structures that are evoked from a combined strength and gymnastics training intervention. Additionally, we aim to calculate whether the training-specific adaptations in physical performance and muscle structure are associated with improved aerial manoeuvre performance in competitive surfers. Aerial manoeuvres are becoming more frequently performed during both surfing training sessions and competitive events. Whilst it is apparent that surfers with superior aerial ability would possess an increased capacity for competitive performance, no research to date has investigated the physical capacities, which may be related to the performance of such manoeuvres. Through determining the training-specific adaptations resulting from combined strength and gymnastics training, it may be possible to increase competitive scoring potential by undertaking specific training to attain desirable training-specific adaptations.

#### ***Who can participate in the research?***

We are seeking any member of the surfing community, with experience in competitive surfing and the ability to perform aerial manoeuvres, to express a desire to participate in the proposed study. To be able to participate you must be aged between 18-35 years of age and will be required to be free of any medical conditions that may identify you to be at higher risk of injury or discomfort during the activities. Participants should have no pre-existing medical issues that may be worsened as a result of completing the research

project. Participants will be required to be actively competing at a minimum of state level competition.

***What choice do you have?***

Participation in this research is entirely your choice. Only those people who provide informed consent will be included in the project. Whether or not you decide to participate, your decision will not disadvantage you. If you do decide to participate, you may withdraw from the project at any time without giving a reason and have the option of withdrawing any data that identifies you.

***What would you be asked to do?***

If you agree to participate, you will be asked to complete the following questionnaires, and training and testing protocols:

*Pre Exercise Health Screening Questionnaire*

The purpose of the Pre-Exercise Health Screening Questionnaire is to ensure you do not have any current or previous health issues that may place you at a risk of injury during the testing.

*Training*

Each participant will be initially randomly allocated to either a combined strength and gymnastics training group, or a control group. You will be required to perform two days of training per week, for six weeks.

*Exercise Testing*

Participation in the proposed study will require you to complete a series of physical tests at the Hurley Surfing Australia High Performance Centre. In the weeks prior to, and following each training intervention, you will complete a restricted anthropometric assessment (height, weight and sum of seven skinfolds) and a battery of physical tests during a single session. Physical tests include; countermovement jump (CMJ), drop depth jump (DDJ), static jump (SJ), isometric mid-thigh pull (IMTP), and the drop and stick. Prior to testing, your muscle and tendon structure will be assessed using ultrasonography. The ultrasonography results will allow for the pennation angle, muscle fibre length, and muscle thickness of vastus lateralis (VL) and lateral gastrocnemius (LG) to be assessed, as well as the length of the Achilles tendon (AT) relative to the muscle-tendon unit.

*Video Recording of Aerial Manoeuvre Performance*

During the weeks both prior to and immediately following the six weeks of training, you will have video-recordings taken of your aerial manoeuvre performance during four one-hour surfing sessions.

***How much time will it take?***

Participants will be required for a total of eight weeks, for two days each week.

***What are the risks and benefits of participating?***

Although unlikely, the study presents some risk to participants in the form of muscle soreness from the training and risk of injury during surfing activity. All training, exercise testing, and surfing is performed in a controlled environment and will be stopped by the researcher if deemed dangerous. As a risk of physical injury may still exist, the researchers will ensure that; surf conditions are suitable based on advice from the surf lifeguards, you have completed a warm-up to minimise the risk of a musculoskeletal injury, and you are familiarised with all training exercises and tests prior to completing the testing.

As a result of participating in the study, you will receive several benefits. You will undergo physical testing, to assess lower-body strength and power, which will be explained in detailed by the researchers and used to individualise your training programs. From the training it is proposed that you should gain a significant increase in fitness. Following the study, you will also receive a report detailing the findings of the study and arising benefits. This report will provide each participant with their final results on each physical test, which measure surfing-specific performance. These results can be used by the participants to assess their surfing-specific fitness, and identify how to further improve their performance.

***How will your privacy be protected?***

The confidentiality of this study is assured. Under no circumstances will any names appear on publications associated with this research. The individual results will be provided to you in verbal and written form with no one else being given the results unless you request it. Hard copies of results will be stored in a locked filing cabinet along with backed up data stored securely in the filing cabinet. All video footage will be stored digitally on a secure university computer and network drive, and will be protected by password. The researchers are the only personnel who have access to the data. Your confidentiality will be ensured by replacing your name with a numerical code. The data will be retained for a minimum of five (5) years, at the Hurley Surfing Australia High Performance Centre.

***How will the information collected be used?***

Data will be presented in scientific journals and conferences following the conclusion of the project. All presentation and use of data will be as group and descriptive measures, not individual responses.

***What do you need to do to participate?***

Please read this Information Statement and be sure you understand its contents before you consent to participate. If there is anything you do not understand, or you have questions, contact the researcher.

If you would like to participate, please email the chief investigator on the details below. You will then be required to complete a pre-exercise health-screening questionnaire and consent form prior to participation.

If you are a suitable participant for this study, you will be informed of this upon completion of the pre-exercise health-screening questionnaire. If the pre-exercise health screen has identified any medical issues, you will be required to seek a medical clearance before being included in the study.

***Further information***

If you would like further information please contact Josh Secomb for further information regarding the study.

Josh Secomb  
Phone: (02) 6671 0000  
Mobile: 0402 446 256  
Email: [josh@surfingaustralia.com](mailto:josh@surfingaustralia.com)

Thank you for considering this invitation.



Josh Secomb

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  
Edith Cowan University  
270 Joondalup Drive  
JOONDALUP WA 6027  
Phone: (08) 6304 2170  
Email: [research.ethics@ecu.edu.au](mailto:research.ethics@ecu.edu.au)

**APPENDIX C - INFORMED CONSENT FORMS**

Mr Josh Secomb  
Strength and Conditioning Scholar/PhD Candidate at Edith Cowan University  
School of Exercise and Health Sciences  
Faculty of Computing, Health and Science  
Hurley Surfing Australia High Performance Centre  
7 Barclay Dr, Mainwaring Precinct, Casuarina, 2487, NSW  
0402446256  
[josh@surfingaustralia.com](mailto:josh@surfingaustralia.com)

Consent Form for the Research Project:

**The physical and muscle architectural differences between higher- and lower-performing aerial surfers**

Document Version 1; dated 7/08/2016

I agree to participate in the above research project and give my consent freely.

I understand that the project will be conducted as described in the Information Statement, a copy of which I have retained.

I understand that the purpose of this study is to identify the physical performance and lower-body muscle architectural differences between higher- and lower-performing aerial surfers.

I understand I can withdraw from the project at any time and do not have to give any reason for withdrawing.

I consent to:

- Undergo pre-screening procedures that involve a health questionnaire and the collection of personal details
- Have my lower-body muscle architecture assessed through ultrasonography
- Complete a battery of physical tests, to assess my lower-body strength and power
- Allow my aerial manoeuvre performance to be assessed and ranked, based on previous competitive performance

I understand that my personal information will remain confidential to the researchers.

I have had the opportunity to have questions answered to my satisfaction. I consent to providing my contact details below so that I can receive a summary report of the findings from the research.

**Print Name:** \_\_\_\_\_

**Signature:** \_\_\_\_\_

**Date:** \_\_\_\_\_

**Contact Details:**

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**Phone:** \_\_\_\_\_

**Email:** \_\_\_\_\_

Mr Josh Secomb  
Strength and Conditioning Scholar/PhD Candidate at Edith Cowan University  
School of Exercise and Health Sciences  
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Consent Form for the Research Project:

**A comparison of the training-specific adaptations of physical capacities and lower-body muscle structure evoked from strength only and gymnastics only training, and the transfer of adaptations to the change in aerial performance**

Document Version 1; dated 7/08/2016

I agree to participate in the above research project and give my consent freely.

I understand that the project will be conducted as described in the Information Statement, a copy of which I have retained.

I understand that the purpose of this study is to compare the training-specific changes in physical capacities and lower-body muscle structure that are evoked from a strength training only and a gymnastics training only intervention.

I understand I can withdraw from the project at any time and do not have to give any reason for withdrawing.

I consent to:

- Undergo pre-screening procedures that involve a health questionnaire and the collection of personal details
- Complete two eight week training interventions, involving both strength only and gymnastics only training
- Have my lower-body muscle architecture assessed through ultrasonography
- Complete a battery of physical tests, to assess my lower-body strength and power
- Allowing video recording of my aerial manoeuvre performance to be used in pre- and post-training analysis by the researchers.

I understand that participation in the research will expose participants to those risks associated with surfing specific movements.

I understand that my personal information will remain confidential to the researchers.

I have had the opportunity to have questions answered to my satisfaction. I consent to providing my contact details below so that I can receive a summary report of the findings from the research.

**Print Name:** \_\_\_\_\_

**Signature:** \_\_\_\_\_

**Date:** \_\_\_\_\_

**Contact Details:**

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**Phone:** \_\_\_\_\_

**Email:** \_\_\_\_\_

Mr Josh Secomb  
Strength and Conditioning Scholar/PhD Candidate at Edith Cowan University  
School of Exercise and Health Sciences  
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I understand that the purpose of this study is to determine the training-specific changes in physical capacities and lower-body muscle structures that are evoked from a combined strength and gymnastics training intervention.

I understand I can withdraw from the project at any time and do not have to give any reason for withdrawing.

I consent to:

- Undergo pre-screening procedures that involve a health questionnaire and the collection of personal details
- Be randomly assigned to a combined strength and gymnastics training group, or a control group
- Complete a six week training intervention involving combined strength and gymnastics training, if randomly assigned
- Have my lower-body muscle architecture assessed through ultrasonography
- Complete a battery of physical tests, to assess my lower-body strength and power
- Allowing video recording of my aerial manoeuvre performance to be used in pre- and post-training analysis by the researchers.

I understand that participation in the research will expose participants to those risks associated with surfing specific movements.

I understand that my personal information will remain confidential to the researchers.

I have had the opportunity to have questions answered to my satisfaction. I consent to providing my contact details below so that I can receive a summary report of the findings from the research.

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**Contact Details:**

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