PADDLING PERFORMANCE IN RECREATIONAL AND COMPETITIVE JUNIOR SURFERS

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ABSTRACT

**Purpose:** The primary purpose of this thesis was to investigate surf-paddling performance, the surf popup manoeuvre (i.e., prone to standing position) and maximal-leg power in junior male recreational and competitive surfers. Four independent studies were conducted with the aims to: i. Develop reliable testing methods of assessing maximal-paddling performance in surfers (Study 1), ii. Determine the aerobic power and paddling economy in junior male recreational surfers (SurfersREC) and junior male competitive surfers (SurfersCOMP) (Study 2), iii. Measure maximal-paddling performance and the accumulated O$_2$ (AO$_2$) deficit of a 30-s Wingate Anaerobic Test for paddling (WAnT$_{PADDLING}$) in SurfersREC and SurfersCOMP (Study 3), and iv. Characterise the timing and magnitude of the vertical ground reaction forces produced during a surf popup manoeuvre in SurfersREC and SurfersCOMP, measure maximal-leg power in SurfersREC and SurfersCOMP, and measure the influence of paddling on the popup maneuver and maximal leg power in SurfersREC (Study 4).

**Methods:** All subjects were junior male surfers aged 16-20 yr. SurfersCOMP were members of the Australian Junior National Team and had been competing nationally for a minimum of 2 yr in national age-group events. SurfersREC had been surfing for a minimum of 4 yr and participating in surfing at least 2 session/wk, but had not participated in competitive surfing events, other than their local board-riding events (<6 event/yr). Participation numbers for each group included; i, Study 1: eleven SurfersCOMP (17±1 yr, 61.9±3.1 kg, 173±2 cm), ii, Study 2: eight SurfersREC (18±2 yr; 66.8±13 kg, 175±10.3 cm) and eight male SurfersCOMP (18±1 yr; 68.0±11.7 kg, 172.9±9.6 cm), iii, Study 3: eight SurfersREC (18±2 yr, 66.7±6.3 kg, 169±10 cm) and eight SurfersCOMP (18±1 yr, 68.9±47 kg, 170±5 cm), iv, Study 4: ten SurfersREC (17±1 yr, 68.2±6.2 kg, 179±5 cm) and ten SurfersCOMP (17±1 yr, 62.9±9.9 kg, 172±8 cm). All paddling tests were performed on a stationary swim-bench ergometer with pulmonary gas exchange measured breath-by-breath using a metabolic measurement system. Aerobic power was
determined using an incremental-paddling test to exhaustion and paddling economy measured during paddling at four, 3-min constant-load work stages. Anaerobic power was measured from a 10-s maximal-paddle test and the 30-s WAnT\textsubscript{PADDLING} test. The AO\textsubscript{2} deficit was determined during the WAnT\textsubscript{PADDLING} as a measure of the contribution of the anaerobic energy systems to the total energy demand of the test. The timing and magnitude of the vertical ground reaction forces produced during the popup were measured on an inground force plate. Maximal vertical jump height was measured on the force plate and used as a measure of leg power. Relationships between paddling, the popup, and leg power were investigated before and after 25 min of paddling on the swim-bench ergometer, designed to replicate a competitive surfing heat.

Results: Study 1 established that peak power determined during a 10-s maximal-paddling test on a swim-bench ergometer is a reliable method both trial-to-trial ($r = 0.995$, $p < 0.001$) and day-to-day ($r = 0.983$, $p < 0.001$) to determine maximal-paddling power in surfers. Study 2 showed that there were no differences between Surfers\textsubscript{REC} and Surfers\textsubscript{COMP} for peak O\textsubscript{2} uptake (2.5 ± 0.5 L/min vs. 2.6 ± 0.4 L/min, respectively) and economy (21.8 ± 3.1 % vs. 23.8 ± 4.0 %, respectively). There were no significant correlations between aerobic power and economy with surfing experience (number of yr surfing) or frequency (session/wk). During submaximal constant-load paddling blood lactate was greater in Surfers\textsubscript{REC} (2.4 ± 0.9 mmol/L) compared to Surfers\textsubscript{COMP} (1.6 ± 0.5 mmol/L). In Study 3 peak power (Surfers\textsubscript{REC} = 292 ± 56 W vs. Surfers\textsubscript{COMP} = 404 ± 98 W, $p = 0.014$), mean power (Surfers\textsubscript{REC} = 236 ± 59 W vs. Surfers\textsubscript{COMP} = 335 ± 74 W, $p = 0.010$), and the AO\textsubscript{2} deficit (Surfers\textsubscript{REC} =1.14 ± 0.38 L vs. Surfers\textsubscript{COMP} = 1.60 ± 0.31 L, $p = 0.022$) determined during the 30-s WAnT\textsubscript{PADDLING} were all greater in Surfers\textsubscript{COMP} when compared to Surfers\textsubscript{REC}. No differences were observed between Surfers\textsubscript{REC} and Surfers\textsubscript{COMP} for peak O\textsubscript{2} uptake (2.5 ± 0.2 L/min vs. 2.7 ± 0.1 L/min, respectively) and paddling economy (19.6 ± 6.9 % vs. 21.1 ± 4.9 %). Significant correlations were observed between surfing experience and frequency with the WAnT\textsubscript{PADDLING} peak power and AO\textsubscript{2} deficit. Consistent with study 2, from the incremental paddling test no
correlations were observed between surfing experience and frequency and peak O\textsubscript{2} uptake and paddling economy. Study 4 revealed no differences between Surfers\textsubscript{REC} and Surfers\textsubscript{COMP} in the timing and magnitude of the vertical ground reaction forces produced during the popup manoeuvre. There were no differences in the leg power as a measure of jump height between Surfers\textsubscript{REC} (38.2 \pm 4.7 cm) and Surfers\textsubscript{COMP} (40.0 \pm 9.2 cm). Following 25 min of intermittent surfboard paddling there was a decrease (t = 4.553, p = 0.001) in maximal vertical jump height in Surfers\textsubscript{REC} (post paddle = 34.0 \pm 5.1 cm).

Conclusions:
No differences in aerobic power and paddling economy between Surfers\textsubscript{COMP} and Surfers\textsubscript{REC} and a greater anaerobic power and accumulated O\textsubscript{2} deficit in Surfers\textsubscript{COMP} compared to Surfers\textsubscript{REC} suggests that the measures of anaerobic performance are more closely related to surfing ability than measures of aerobic performance. No correlations between aerobic power and paddling economy with surfing experience and participation frequency, but significant correlations between anaerobic power and the accumulated O\textsubscript{2} deficit with surfing experience and participation frequency reveal that measures of anaerobic performance are more closely associated with surfing experience and participation frequency than measures of aerobic performance. A decrease in maximal vertical jump height following surfboard paddling suggests that paddling may influence leg power possibly necessary for subsequent wave-riding performance. Collectively these findings suggest that recreational and competitive surfing results in significant changes in the anaerobic energy system, more so that the aerobic energy system and than a bout of paddling can reduce leg power.
DECLARATION

This work has not previously been submitted for a degree or diploma in any university. To the best of my knowledge the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

_________________________      ______________________
Signed                       Dated
LIST OF PUBLICATIONS

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Danielle
In 1999, at a university open day, a well established Professor and Head of the Physiotherapy and Exercise Science Department passed on a piece of insight to a fresh faced 17 year old. The Professor said with a grin of encouragement “you’ll do fine at the university here on the Gold Coast, as long as you don’t spend too much time surfing or hanging on the beach”. Ten years later I can confidently respond “sorry Professor, on this one occasion you were wrong”.

Surfboard riding (Surfing) was once considered a leisure activity for the ‘beach hippies’ of the 60’s and 70’s. Forty years later it is now a highly competitive international sport with an estimated 4 million participants spread across all continents and supported by many millions of dollars in competition prize money and sponsorship. The growth of surfing has seen an increase in participation numbers, competition standards and surfing performance. As with other elite sports, the improvements in performance have occurred through substantial advances in equipment design and improvements in the biomechanical, physiological and psychological profile of surfboard riders (surfers). Although technical advances are clearly documented, there is a paucity of scientific evidence relating to the human performance aspects of the sport. The lack of research in this field probably relates to the young age of the sport, which was introduced to Australia in the early 1910’s but did not achieve significant participation levels until the 1950’s. Further, research on surfing is complex due to the many uncontrollable variables that influence surfing performance. These include the geographical and environmental conditions of the ocean, such as the type of ocean floor (sand, rock, reef), wave size and direction, wind speed and direction and tide and current movements.

Exercise science research in surfing began in the 1980’s, with exercise physiologist Brian. J. Lowden publishing a series of papers investigating the physical attributes, movement patterns, and common injuries of competitive surfers. Following the
conclusion of Lowdon’s research, the early 1990’s produced only a few articles, mainly investigating injury patterns in recreational and competitive surfers. Only in the last 5 years have we seen a resurgence in publications in surfing physiology and surfing biomechanics. In particular, A. Mendez-Villanueva, a Spanish researcher who completed the first PhD in surfing physiology published a number of papers, including a review of the ‘Physiological Aspects of Surfboard Riding Performance’, which covered the exercise science research undertaken in surfing up until 2005.

With the limited amount of scientific research on surfing, the physiological and biomechanical factors important for optimal surfing performance are still unclear. Such information is valuable for surfing instructors and coaches, as well as health professionals, to help target strategies for exercise training and performance improvement as well as for the prevention and management of injuries. This PhD thesis reports on scholarly and research activity aimed at expanding the understanding of the key physiological and biomechanical determinants of surfing performance.

The thesis is presented in six parts: Chapter 1 provides an overview of the background knowledge of surfing physiology. The history and movement patterns of surfing are introduced and the physiological demands of surfing and the physiological characteristics of surfers explored. The research aims of the thesis are presented in the final section of chapter 1. Chapters 2, 3, 4 and 5 describe four original experimental studies that address each of the research aims. Each of these chapters includes independent Introduction, Methods, Results and Discussion sections. Chapter 2 reports ‘Two reliable protocols for assessing maximal-paddling performance in surfboard riders’ (Study 1). Chapter 3 discusses the ‘Peak aerobic power and paddling economy in recreational and competitive junior surfers’ (Study 2). Chapter 4 presents ‘Maximal-paddling performance in recreational and competitive junior surfers’ (Study 3) and Chapter 5 reports the final study ‘Surfboard riding popup manoeuvre and leg power in recreational and competitive junior surfers’ (Study 4). Chapter 6 concludes with the
thesis discussion and conclusions, summarising the findings of all four studies and discussing the relevance of this research to the existing scientific literature on surfing.