Competition and training demands of junior Sprint Kayak athletes

A thesis submitted for the degree

Doctor of Philosophy

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By

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I certify that the work in this thesis has not previously been submitted for a degree at the University of Technology Sydney nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me, Thiago Oliveira Borges. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Signature of Student

_____

Date

Acknowledgements

"I have a kind of duty, duty of dreaming, always dreaming
as being more than a spectacle of myself,
I have to have the best show I can.
And so, I build myself in gold and silk, in rooms
alleged, I invent a stage, scenery to live my dream
amongst mild lights and invisible music."

Fernando Pessoa

A PhD is a very difficult task to be accomplished in someone's life. It starts as a complex dream and like a puzzle, all the pieces are put in place at their own time and all of a sudden, these pieces are in place and the dream finally come true. However, like any big puzzle, the pieces are put together easier with help, and I am very grateful for everyone that has helped me in any way to complete this PhD. Thank you.

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Preface

This thesis for the degree of Doctor of Philosophy is in the format of published, submitted or ready for submission manuscripts and abides by the 'Procedures for Presentation and Submission of Theses for Higher Degrees – University of Technology, Sydney; Policies and Directions of the University'. All manuscripts included in this thesis are closely related in subject matter and form a cohesive research narrative.

Based on the research design and data collected by the candidate, two manuscripts have been published, one has been submitted for publication and three are ready to be submitted, in peer-reviewed journals. These papers are initially brought together by an *Introduction*, which provides background information, defines the research problem and the aim of each study. Then, a *Literature Review* provides an overview of previous knowledge that characterizes Sprint Kayak performance, methods for measure training, performance and physiological responses of Sprint Kayak and means to improve those variables. A logical sequence following the development of research ideas in this thesis is presented in manuscript form (*Chapter 3 to Chapter 8*).

Each manuscript outlines and discusses the individual methodology and the findings of each study separately. The *General Discussion* chapter provides an interpretation of the collective findings and practical applications from the series of investigations conducted. Lastly, a final *Summary and Recommendations* chapter summarizes the research hypothesis and conclusions from each project. Future research is suggested on the basis of the findings from the studies. Author-date reference style has been used throughout the document and the reference list is at the end of the thesis.

List of Articles Submitted for Publication

Refereed Journal Publications

- **Oliveira Borges, T.**, Bullock, N. and Coutts, A.J. Pacing characteristics of international Sprint Kayaks athletes. *Int J Perf Analysis in Sports*. 13: 353-364, 2013.
- **Oliveira Borges, T.**, Dascombe, B. J., Bullock, N. and Coutts, A.J. (*Prepared for submission*). Physiological characteristics of well-trained junior Sprint Kayak athletes. *Eur J Sports Sci.*
- **Oliveira Borges, T.**, Bullock, N., Newton, J. and Coutts, A.J. (*under review*). A new field test for assessing and monitoring Sprint Kayak athletes. *J Sports Sci.*
- **Oliveira Borges, T.**, Bullock, N., Duff, C. and Coutts, A.J. Methods for quantifying training in Sprint Kayak. *J Strength Cond Res. Published ahead of print. DOI:10.1519/JSC.0b013e31829b56c4*
- **Oliveira Borges, T.**, Bullock, N., Dascombe, B.J. and Coutts, A.J. (*Prepared for submission*). The acute response of common repeated sprint and high-intensity aerobic training sessions in Sprint Kayak athletes. *J Strength Cond Res.*
- **Oliveira Borges, T.**, Bullock, N., Dascombe, B.J. and Coutts, A.J. (*Prepared for submission*). Comparison of the acute physiological responses of repeated sprint and high-intensity aerobic training sessions in Junior Sprint Kayak athletes. *Int J Sports Phys Perf.*

Conference Proceedings & Abstracts

- **Oliveira Borges, T.**, Bullock, N., Dascombe, B.J. and Coutts, A.J. (2013). *Comparison of high-intensity aerobic and repeated sprint training on performance and physiological variables of junior Sprint Kayak athletes.* Oral communication presented at the European College of Sport Sciences, Barcelona, Spain.
- **Oliveira Borges, T.**, Bullock, N., Dascombe, B.J. and Coutts, A.J. (2013). *Correlates of whole body and muscle oxygen on kinetics, physiological variables and performance in Sprint Kayak.* Mini - oral communication presented at the European College of Sport Sciences, Barcelona, Spain.

Statement of Candidate Contribution

The contribution of each author to the investigations undertaken as part of the thesis is outlined in Table A below.

Table A: Percentage contribution (%) of each author to the investigations conducted during the candidature.

Author	Study 1			Study 2				Study 3			
	Thiago Oliveira Borges	Nicola Bullock	Aaron Coutts	Thiago Oliveira Borges	Nicola Bullock	John Newton	Aaron Coutts	Thiago Oliveira Borges	Ben Dascombe	Nicola Bullock	Aaron Coutts
Research design	80%	10%	10%	70%	10%		20%	70%	5%	5%	20%
Ethics Application				70%	10%		20%	70%		10%	20%
Subject recruitment				30%	20%	50%		90%		10%	
Data collection	100%			70%	10%	20%		90%			10%
Data analysis	60%		40%	80%	10%		10%	80%	10%		10%
Statistical analysis	50%		50%	80%			20%	80%			20%
Manuscript Preparation	100%			100%				100%			
Manuscript Revision		25%	75%		30%		70%		10%	10%	80%

Table A (*cont.*): Percentage contribution (%) of each author to the investigations conducted during the candidature.

Author	Study 4				Study 5				Study 6			
	Thiago Oliveira Borges	Nicola Bullock	Christine Duff	Aaron Coutts	Thiago Oliveira Borges	Nicola Bullock	Ben Dascombe	Aaron Coutts	Thiago Oliveira Borges	Nicola Bullock	Ben Dascombe	Aaron Coutts
Research design	80%	10%		10%	70%	10%	10%	10%	80%	10%		10%
Ethics Application	80%	10%		10%	80%			20%	80%	10%		10%
Subject recruitment	40%	10%	50%		90%	10%			90%	10%		
Data collection	90%		10%		90%			10%	90%	10%		
Data analysis	100%				90%			10%	70%	10%	10%	10%
Statistical analysis	90%			10%	100%				90%			10%
Manuscript Preparation	100%				100%				100%			
Manuscript Revision		25%		75%		10%	20%	70%		15%	15%	70%

Abstract

Introduction: Sprint Kayak is an Olympic sport where women race over 200-m and 500-m and men compete over 200 and 1000-m. In 2009 the 200-m event was included into the Olympic Games' program replacing the men's 500-m events and providing the women with an additional event. Currently, little research is available on the demands of the 200-m event. With the inclusion of this short distance event, the training practices require review, especially in the case of young developing athletes, as this group may begin to specialise their training toward this new format. Therefore, the overall goals of this thesis were to: 1) gain a better understanding of the racing and physiological demands in Sprint Kayak, 2) develop specific methods for monitoring training and performance and 3) compare methods for training well-trained junior Sprint Kayak athletes. The results of four separate studies were reported in six manuscripts.

Study 1: The split –time results from six Sprint Kayak world championships (n_{total} = 486) were pooled and the pacing strategies and performance analysed according to race level (Finals A and B) and boat (K1, K2 and K4). Collectively, the world-class Sprint Kayak athletes present different pacing strategy according to final A and B), boat class (K1, K2 and K4) and from year to year.

Study 2: Examined the relationships between physiological variables, including $\dot{V}O_2$max, maximal aerobic power (MAP), lactate threshold (LT_2), whole body ($\dot{V}O_{2kinetics}$) and muscle oxygen kinetics ($MO_{2kinetics}$), muscle oxygenation parameters and on-water time-trial performances. The results showed physiological variables correlated with performance in both 200-m and 1000-m events. Furthermore, the muscle oxygenation parameters increased the predictive power of these physiological variables highlighting the importance of muscle oxygen extraction for the 200-m time-trial.

Study 3: Tested a specific performance test (SK_{test}) in the laboratory and in the field for validity (as a performance and fitness measure) and reliability (part A). In addition, the test sensitivity was assessed during a normal training period (part B) in a separate group of well-trained junior Sprint Kayak athletes. Part A - Participants (n = 11) completed a standard incremental kayak step test in the laboratory, a SK_{test} consisting of two sets of ten 100-m efforts with 20 s rest between efforts and 1000-m between sets in both laboratory and on-water and on-water time trials over 200 and 1000-m. Part B – Another group of athletes (n = 8) performed weekly trials of the short version of the SK_{test} for four weeks, in their usual training environment. The results showed the SK_{test} to be valid, reliable and sensitive for monitoring fitness and performance changes.

Study 4: Tested the validity of methods for quantifying training load and established the relationships between training loads, physiological variables and on-water performance in well-trained junior Sprint Kayak athletes. The results demonstrated the validity of the session-RPE method for quantifying training loads in Sprint Kayak. Moreover, the inverse relationships between physiological variables, performance and training loads showed that aerobically fitter and faster athletes have lower perceived training loads when external loads are controlled.

Study 5: Compared the power outputs and acute physiological responses (i.e. heart rate [HR], blood lactate [BLa^-], $\dot{V}O_2$, and tissue saturation index [TSI])) of common repeated sprint (RS) and high-intensity aerobic (HIA) interval training sessions in well-trained junior Sprint Kayak athletes. Two different RS training sessions consisting of a shorter 10 s repeat effort session (2 sets of 10 s efforts with 10 s rest between efforts and eight minutes between sets) and a longer 30-s repeat effort session (6 x 30 s efforts with 210 s rest). The HIA sessions included a shorter (2 x 3 min efforts with 3 min rest between efforts, and 5 min between sets) and a longer 2-km (3 x 2 km efforts on a 15

min cycle) interval training sets. The results showed the physiological responses and external loads to the main body the HIA interval sessions were considerably different from RS sessions, with the exception of TSI which was similar for all. Mixed modelling showed significant random variation for the time spent in different training zones for mean power output and $\dot{V}O_2$. The present study highlighted distinct differences in the HR, $\dot{V}O_2$, [BLa^-], and perceptual responses to common RS and HIA training, with the shorter RS sessions placing a greater stimulus on glycolytic pathways, and the longer HIA sessions requiring greater energetic demands. Importantly, *large* inter-individual physiological responses were observed across each of the different training sessions. These findings highlight the need to individualise training programs for Sprint Kayak based on the athletes' characteristics and demands of competition.

Study 6: Compared the effects of 5 weeks of RS and HIA interval training on physiological ($\dot{V}O_2$max, MAP, LT_2, $\dot{V}O_{2kinetics}$ and $MO_{2kinetics}$) and performance (200 and 1000-m on water time trial) variables in well-trained junior Sprint Kayak athletes using matched-groups randomised design. The groups were matched for physical fitness and on-water kayak performance. In addition to their usual training, the RS training group completed a shorter 10 s repeat effort session (2 sets of 10 s efforts with 10 s rest between efforts and 8 minutes between sets) and longer 30-s repeat effort session (6 x 30 s efforts with 210 s rest), where each session was completed once per week. Similarly, the HIA interval training group completed a three-minute (2 x 3 min efforts with 3 min rest between efforts and 5 min between sets) and longer 2-km aerobic training (3 x 2 km efforts on a 15 min cycle) session once each week during the study in addition to their usual training. Results showed that the RS and HIA interval training interventions elicited *trivial* changes in maximal indicators of aerobic fitness (i.e. $\dot{V}O_2$max and maximal HR) and *trivial* and *small* on-water performance (i.e. time trials

over 200 and 1000-m, respectively) in both groups. In contrast, submaximal physiological responses (i.e. lactate threshold) were *trivial* whereas oxygen kinetics presented *small-to-moderate* improvements after five weeks (~19 training sessions) performed by both RS and HIA groups. This information suggests that physiological and performance characteristics are very stable in well-trained junior Sprint Kayak athletes. It seems that either larger loads of RS or HIA interval training or longer training periods are required to elicit larger changes in specific physiological adaptations in well-trained junior Sprint Kayak athletes.

Keywords

Sprint Kayak

Performance

Training

Training loads

Aerobic fitness

Oxygen kinetics

Muscle oxygenation

Pacing

Field Testing

Validity

Reliability

Sensitivity

Perceived Exertion

Mixed Modelling

List of Abbreviations

% HRmax	maximal heart rate percentage
µL	microlitre
AIS	Australian Institute of Sport
ANOVA	analysis of variance
A_p	asymptotic amplitudes for the primary exponential component
A_s	asymptotic amplitude for the slow exponential component
ATP	adenosine triphosphate
$[BLa^-]$	blood lactate concentration
C1	canoe single
C2	canoe double
CI	confidence intervals
CR-10	category-ratio scale
CV	coefficient of variation
EEO_2	end-exercise o_2 value
G_o	total gain
G_p	primary gain
GPS	global positioning system
G_s	slow gain
η^2	partial eta squared
HHb	deoxyhaemoglobin
HR	heart rate
$HR_{exercise}$	exercise heart rate
HRmax	maximal heart rate
HR_{rest}	rest heart rate
ICC	intraclass correlation
ICF	international canoe federation
In	natural logarithm
IRK	internationale repräsentantenschaft kanusport
iTRIMP	individualized training impulse
K1	kayak single
K2	kayak double
K4	kayak four
$L \cdot min^{-1}$	litres per minute
LT_1	aerobic threshold
LT_2	lactate threshold
m	Metre
MAP	maximal aerobic power
min	Minute
$mL \cdot kg^{-1} \cdot min^{-1}$	millilitres per kilogram per minute
mm	millimetre
$mmol \cdot L^{-1}$	mill moles per litre
N	sample size
NIRS	near infrared spectroscopy
O_2Hb	Oxyhaemoglobin
O_2 (t)	o_2 at a given time
PCr	phosphocreatine
r	correlation coefficient

r^2	determination coefficient
RPE	ratings of perceived exertion
RSA	repeated sprint ability
RSS	residual sum of squares
s	seconds
SD	standard deviation
SK_{test}	sprint kayak test
session-RPE	ratings of perceived exertion of the training session
SPSS	statistical package for social science
SWT	squared wave submaximal tests
tHb	total haemoglobin
TD_p	time delay for the primary exponential component
TD_s	time delay for the slow exponential component
TE	typical error
TEM	technical error of measurement
TL	training loads
τ^s	time constants for the primary exponential component
TRIMP	training impulse
iTRIMP	individualized training impulse
τ^s	time constants for the slow exponential component
TSI	tissue saturation index
TSS	total sum of squares
TT	time trial
UTS	University of Technology, Sydney
Vmax	highest speed
V_{min}	lowest speed
$\dot{V}O_2$	oxygen uptake
$\dot{V}O_2max$	maximal oxygen uptake
W	Watts
wMRT	weighted mean response time
ΔHR_{ratio}	rate of heart rate elevation

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