Establishing the Validity of Methods for Quantifying Training Load in Endurance Athletes

A thesis submitted for the degree

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by

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CERTIFICATE OF AUTHORSHIP AND ORIGINALITY OF THESIS

I certify that the work contained in this thesis has not been previously submitted either in whole or in part for a degree at the University of Technology, Sydney or any other tertiary institution.

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

Production Note:
Signature removed prior to publication.

Lee Wallace

27/7/12

Date Submitted

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PREFACE

This thesis for the degree of Doctor of Philosophy is in the format of published or submitted 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'.

Based on the research design and data collected by the candidate, four manuscripts have been submitted for publication in peer reviewed journals. These papers are initially brought together by an *Introduction*, which provides background information, an explanation of the research problem and the aims of the series of studies. A *Literature Review* then follows to provide an overview of quantifying training load and systems modelling research. The body of the research is presented in manuscript form, in a logical sequence following the development of research ideas in this investigation. Each manuscript outlines and discusses the individual methodology and the findings of each study separately. Figures, tables and reference numbering in all manuscripts have been retained. These chapters are formatted according to the journal requirements and as such may be slightly different from each other. The *Summary* chapter integrates the flow of research ideas and conclusions from each project and outlines directions for future research.

LIST OF ARTICLES SUBMITTED FOR PUBLICATION

Refereed Journal Publications

1. **Wallace, L.K.**, Slattery, K.M., & Coutts, A. J. (2011). A comparison of methods for quantifying training load: relationships between modelled and actual training responses. *Medicine and Science and Sports and Exercise.* In review.

2. **Wallace, L.K.**, Slattery, K.M., & Coutts, A. J. (2011). Establishing the criterion validity and reliability of common methods for quantifying training load. *European Journal of Applied Physiology.* in review.

3. **Wallace, L.K.**, Slattery, K.M., & Coutts, A. J. (2008). The ecological validity and application of the session-RPE method for quantifying training loads in swimming. *Journal of Strength and Conditioning Research*: *23*(1): 33-8.

4. **Wallace, L.K.**, Slattery, K.M., Simpson, N., Bell. J., & Coutts, A. J. (2008). Using session-RPE to monitor training load in swimming. *Strength and Conditioning Journal: 30*(6):72 - 76.

5. Slattery, K.M, **Wallace L.K.** and Coutts, A.J. (2011). Nutritional practices of elite swimmers during an intensified training camp: with particular reference to antioxidants. *Journal of Sports Medicine and Physical Fitness.* accepted.

6. Slattery, K.M., **Wallace, L.K.**, Bentley, D.J. and Coutts, A.J. (2012). Effect of training load on simulated team sport match performance. *Applied Physiology, Nutrition and Exercise Metabolism.* in review.

Conference Proceedings & Abstracts

1. **Wallace, L.K.,** Slattery, K.M. Coutts, A.J. (2011*). A comparison of methods for quantifying training load: relationships between modelled and actual training responses.* Paper presented at the 16th Annual Congress of the European College of Sports Science, Liverpool, UK.

2. Slattery, K. M**., Wallace, L.K.**, Coutts, A. J., & Bentley, D. J. (2007). Effects of HIGH vs. LOW training loads on metabolic, immune and oxidative markers in team sport athletes. *Journal of Science and Medicine in Sport, 10*(6 (Supplement)), 117.

3. Coutts, A.J., K.M. Slattery, **L.K. Wallace** & Sirotic, A.C. (2007). *Influence of between-match training load on match running performance and markers of recovery in team sport athletes.* Journal of Science and Medicine in Sport, *6* (Supplement 10), 23.

4. Slattery. K.M., **Wallace. L.K**, Coutts. A.J. & Bentley. D. (2007). *Effects of High vs Low training loads on metabolic, immune and oxidative markers in team sport athletes*. Paper presented at the Australian Conference of Science and Medicine in Sport, Adelaide, Australia.

5. **Wallace, L.K.,** Slattery, K.M., & Coutts, A.J. (2007). A comparison between methods for quantifying training load during endurance exercise. *Journal of Science and Medicine in Sport, 10* (6 (Supplement)), 118.

6. **Wallace, L.K.**, Slattery, K.M. and Coutts, A.J. (2005). *The efficacy of psychological state measures for the early detection of overreaching.* Paper presented at the 2005 Australian Conference of Science and Medicine in Sport, Melbourne, Australia.

7. Slattery, K.M., **Wallace, L.K.** and Coutts, A.J. (2006). *Nutritional practices of elite swimmers during an intensified training camp: with particular reference to antioxidants.* Poster presented at the 2006 Australian 2nd Conference of the Australian Association for Exercise and Sport Scientists, Sydney, Australia.

8. Slattery, K.M., **Wallace, L.K.** and Coutts, A.J. (2005). *Practical tests for monitoring fatigue and recovery in triathletes.* Paper presented at the 2005 Australian Conference of Science and Medicine in Sport, Melbourne, Australia.

ABSTRACT

Athletic performance is improved via the systematic application of successive bouts of exercise. However, there is no current consensus on the most accurate method to assess the cumulative effects of physical training. Therefore, the overall aim of this thesis was to determine the criterion validity and reliability of commonly used training load methods to quantify the dose-response relationship between physical training and athletic performance. To achieve this, a series of three studies were completed. Study 1 determined the ecological validity of the session-RPE method for quantifying training loads in elite swimmers. The findings demonstrated strong relationships between session-RPE, heart rate (HR) methods and distance. These results suggest that session-RPE may provide a practical, non-invasive method for quantifying internal training load in competitive swimmers. The purpose of Study 2 was to compare the criterion validity and test-retest reliability of common methods for quantifying training load in endurance exercise. Participants completed either steady state or interval cycle training sessions where oxygen consumption, HR, rating of perceived exertion (RPE) and blood lactate measures were taken to assess the workload of each exercise bout. The results of this investigation showed that external work was the most valid and reliable method for quantifying training load. Heart rate measures were found to be the most valid and reliable measure of internal training load. Finally, the ability of these measures to quantify the training load accumulated over successive training sessions was examined in Study 3. A mathematical model was applied to the physical training completed by male runners over a 15 week period. The findings of this study showed that each of the training load methods investigated are appropriate for quantifying endurance exercise. Collectively, this thesis shows that the validity of the training load measure is influenced most by the reliability of the device used for

measuring training intensity and the degree to which the weighting factors for the calculation of the training load methods are customised to individualised performance parameters.

KEYWORDS

Endurance

Fatigue

Fitness

Heart rate

Heart rate variability

Monitoring training

Performance

Psychological questionnaires

Rating of perceived exertion

Reliability

Session-RPE

Systems models

Training load

TRIMP

Validity

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
AU	arbitrary units
b	male / female weighting factor for TRIMP calculation
beats·min^{-1}	beats per minute
[BLa$^-$]	blood lactate concentration
[BLa$^-$]$_{peak}$	peak blood lactate concentration
CI	confidence interval
cm	centimetre
CR	category ratio
CV	coefficient of variation
d	Cohen's d effect size
D	duration of training sessions
DALDA	Daily Analysis of Life Demands for Athletes
FT	fast twitch
g	grams
GOVSS	gravity ordered velocity stress score
GPS	global positioning system
h	hour
HF	high frequency
HR	heart rate
HR_{ex}	heart rate during exercise
HR_{max}	maximal heart rate
HR_{mean}	mean heart rate
HR_{rest}	resting heart rate
HRV	heart rate variability
HR-$\dot{V}O_2$	heart rate-oxygen uptake
ICC	Interclass correlation coefficient
ip	positive influence of training on performance
J·kg^{-1}	joules per kilogram

k	TRIMP coefficient
kg	kilogram
kJ	kilojoule
km	kilometre
km·h^{-1}	kilometres per hour
L	litre
LF	low frequency
LIR	low-intensity running
L·min^{-1}	litres per minute
m	metre
min	minute
min·s^{-1}	metres per second
mL·kg^{-1}·min^{-1}	millilitres per kilogram per minute
mmol·L^{-1}	millimoles per litre
m·min^{-1}	metres per minute
ms	millisecond
m/s	metres per second
n	number
np	negative influence of training on performance
p	performance
POMS	profile of mood states
r	correlation coefficient
RCP	respiratory compensation point
RPE	rating of perceived exertion
rpm	revolutions per minute
rTSS	running Training Stress Score
s	seconds
SD	standard deviation
sRPE	session-RPE
SS	steady state
t	time

TE	typical error
TEM	technical error of measure
TEM%	percentage technical error of measure
t_g	time prior to competition for maximal performance
TL	training load
t_n	time prior to competition when training is reduced
TQR	Total Quality of Recovery Questionnaire
TRIMP	training impulse
TSS	training stress score
$\dot{V}CO_2$	carbon dioxide expired
VE	ventilation
V_{max}	peak aerobic running velocity
$\dot{V}O_2$	oxygen uptake
$\dot{V}O_2max$	maximal oxygen uptake
$\dot{V}O_2mean$	mean oxygen uptake
$\dot{V}O_2peak$	peak oxygen uptake
VT	ventilatory threshold
VT_1	first ventilatory threshold
VT_2	second ventilatory threshold
w	work
W	watt
W_{final}	workload in the final completed stage of an incremental test
W_{inc}	workload increment of an incremental test
$W \cdot kg^{-1}$	watts per kilogram
W_{max}	maximum work capacity
$W \cdot min^{-1}$	watts per minute
wt	worktime
y	year
µL	microlitre
%	percentage
%BM	percentage of body mass

$\%W_{max}$	percentage of maximum work capacity
°	degrees
~	approximation
ΔHR ratio	average change in heart rate reserve
$\sum$	sum

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