Physiological responses to “all-out” and even-paced cycling intervals

Emma K. Zadow

2012

This thesis is submitted as partial fulfilment of the requirements for the degree of Bachelor of Sports Science (Honours) at Murdoch University, Perth, Western Australia.
I declare that this thesis is my own account of my research and contains, as its main content, work which has not previously been submitted for a degree at any tertiary education institution.

(Miss Emma K. Zadow)
COPYRIGHT ACKNOWLEDGEMENT

I acknowledge that a copy of this thesis will be held at the Murdoch University Library.

I understand that, under the provisions of s51.2 of the Copyright Act 1968, all or part of this thesis may be copied without infringement of copyright where such a reproduction is for the purposes of study and research.

This statement does not signal any transfer of copyright away from the author.

Signed:

Full Name of Degree: Bachelors of Sports Science with Honours

Thesis Title: Physiological responses to “all-out” and even-paced cycling intervals

Author: Miss Emma K. Zadow

Year: 2013
ACKNOWLEDGEMENTS:

The completion of this thesis has been both challenging, yet rewarding and could not have occurred without the invaluable support and guidance from a number of individuals:

To my supervisors, Dr Jeremiah Peiffer and Dr Chris Abbiss, I really could not have asked for better supervisors than yourselves. Your support, advice, encouragement, guidance and patience throughout this process have been second to none and I am extremely lucky to have benefited from your wisdom and your knowledge.

To Miss Nikky Gordon, thank you for being my partner in crime throughout this process and making me laugh throughout the many long hours spent inside the lab, here’s too many more to come.

A study like this could not have occurred without all of the willing participants who selflessly volunteered their time to assist with this project, even with a 5am start, a 9 pm finish and weekend and public holiday sessions, thank you. It was a pleasure too work with you and you may be recalled at a future date...

Last but not least, to my family, the Zadow’s, the Hand’s, the Walker’s and the Waghela’s, thank you for all of your encouragement and support throughout this rollercoaster ride of a year. You have been there for me during the highs and the lows and I know you will continue to support any of my crazy future endeavours, THANK YOU!!!
# TABLE OF CONTENTS

**ACKNOWLEDGEMENTS:** ........................................................................................................ IV

**TABLE OF FIGURES** ........................................................................................................ VII

**TABLE OF TABLES** ........................................................................................................ VIII

**ABSTRACT** ......................................................................................................................... 1

**DEFINITION OF TERMS** ................................................................................................... 3

**ABBREVIATIONS** ................................................................................................................ 4

**CHAPTER ONE: INTRODUCTION** ...................................................................................... 5

1.1. BACKGROUND TO THE STUDY ..................................................................................... 5

1.2. PURPOSE STATEMENT/ SIGNIFICANCE OF RESEARCH ............................................. 7

1.3. RESEARCH QUESTIONS .................................................................................................. 8

1.4. HYPOTHESES ................................................................................................................. 9

1.5. LIMITATIONS ................................................................................................................ 9

1.6. DELIMITATIONS ........................................................................................................... 10

**CHAPTER TWO: CRITICAL REVIEW OF THE LITERATURE** ............................................. 11

2.1. OVERVIEW ..................................................................................................................... 11

2.2. PHYSICAL DEMANDS OF CYCLING .......................................................................... 13

2.3. CYCLE TRAINING: THE 80:20 SPLIT ....................................................................... 14

2.4. PHYSIOLOGICAL, METABOLIC & PERFORMANCE RESPONSES TO HIGH-INTENSITY INTERVAL TRAINING .................................................................................. 15

2.4.1. PHYSIOLOGICAL AND METABOLIC RESPONSES .............................................. 15

2.4.2. PERFORMANCE RESPONSES ............................................................................... 20

2.5. PACING STRATEGIES DURING INTERVAL TRAINING ................................................ 21

2.5.1. "ALL-OUT" PACING SELECTION ........................................................................... 22

2.5.2. EVEN - PACING SELECTION ............................................................................... 24

2.6. SUMMARY ..................................................................................................................... 25

**CHAPTER THREE: METHODS** ........................................................................................... 26

3.1. STUDY DESIGNS .......................................................................................................... 26

3.2. SAMPLING METHODOLOGY ...................................................................................... 26
3.3. PROCEDURES ........................................................................................................27
3.4. DATA PROCESSING ............................................................................................30
   3.4.1 POWER ...........................................................................................................30
   3.4.2 METABOLIC DATA .......................................................................................31
3.5. STATISTICAL ANALYSIS ....................................................................................31

CHAPTER FOUR: RESULTS .....................................................................................33
4.1 INTERVAL MEASUREMENTS ............................................................................33
   4.1.1 POWER MEASUREMENTS ............................................................................33
   4.1.2 METABOLIC MEASUREMENTS ....................................................................35
   4.1.3 HEART RATE MEASUREMENTS ....................................................................37
   4.1.4 PERCEPTUAL MEASUREMENTS ....................................................................38
4.2 TIME TRIAL MEASUREMENTS ........................................................................39
   4.2.1 POWER MEASUREMENTS ............................................................................39
   4.2.2 EVA ANALYSIS .............................................................................................40
   4.2.3 HEART RATE MEASUREMENTS .....................................................................40
   4.2.4 ASSESSMENT OF SECOND “ALL-OUT” TRIAL .........................................40

CHAPTER FIVE: DISCUSSION ...............................................................................41
CONCLUSION ............................................................................................................46
FUTURE DIRECTIONS ...............................................................................................47
REFERENCES ............................................................................................................48
APPENDIX 1: ETHICS APPROVAL LETTER ..............................................................57
APPENDIX 2: VISUAL ANALOGUE SCALES ............................................................58
   2.1 BORG’S RATING OF PERCEIVED EXERTION .............................................58
   2.2 QUADRICEP PAIN AND EFFORT SCALES ................................................59
TABLE OF FIGURES

FIGURE 1. CYCLING INTENSITY AND VOLUME OF ELITE SPANISH U23 CYCLISTS
TRAINING IN THE PERIOD NOVEMBER TO JUNE. DATA REDRAWN FROM ZAPICO ET AL. [48] ......................................................... 15

FIGURE 2. MEAN (± SD) PEAK (A), HIGHEST 30 S MEAN (B) AND AVERAGE POWER OUTPUT (C) MEASURED DURING INTERVALS 1-3 (INT 1–INT 3) IN THE “ALL-OUT”, COMPUTER- AND ATHLETE-CONTROLLED INTERVAL CONDITIONS........ 33

FIGURE 3. MEAN (± SD) RELATIVE VO₂ (A) AND TIME SPENT AT 85% OF VO₂MAX (B)
MEASURED DURING INTERVALS ONE TO THREE (INT1–INT3) IN THE “ALL-OUT”,
COMPUTER- AND ATHLETE-CONTROLLED INTERVAL SESSIONS.. ........................ 35

FIGURE 4. MEAN (± SD) MEASURES OF AVERAGE POWER ACHIEVED IN 4 KM TIME TRIAL FOLLOWING THE “ALL-OUT”, COMPUTER- AND ATHLETE-CONTROLLED INTERVAL SESSIONS. ........................................................................................................... 39
TABLE OF TABLES

TABLE 1. TRAINING CHARACTERISTICS OF PROFESSIONAL ROAD CYCLISTS DURING THE YEAR. REPRODUCED FROM LUCIA ET AL. [42] .......................................... 13

TABLE 2. PHYSIOLOGICAL AND METABOLIC BENEFITS OF HIGH-INTENSITY TRAINING VS. CONTINUOUS TRAINING ................................................................. 18

TABLE 3. PERFORMANCE RESPONSES TO HIGH-INTENSITY INTERVAL TRAINING ...... 23

TABLE 4. MEAN (± SD) HEART RATE (BPM) MEASURED DURING EACH INTERVAL IN THE “ALL-OUT”, COMPUTER-CONTROLLED AND ATHLETE-CONTROLLED CONDITIONS. .............................................................................. 37

TABLE 5. MEAN (± SD) RATINGS OF PERCEIVED EXERTION, QUADRICEP PAIN AND EFFORT MEASURED AT COMPLETION OF EACH INTERVAL IN THE “ALL-OUT”, COMPUTER-CONTROLLED AND ATHLETE-CONTROLLED CONDITIONS. ........... 38
ABSTRACT

Background: Endurance cyclists typically devote ~20% of their training regimens to performing low-volume high-intensity interval training which is associated with large physiological and performance benefits. The relationship between intensity and duration is important during high-intensity interval training as both can profoundly influence metabolic energy expenditure, fatigue development and subsequent adaptations. Purpose: Within the literature, most interval training is delivered using either an "all-out" or even-paced approach; however, to the author’s knowledge no study has yet compared the metabolic stress, perceived exertion and fatigue resulting from such intervals. Therefore, this study compared the physiological and perceptual responses to matched mechanical work interval bouts using “all-out” and two different even-paced methodologies (i.e. computer- and athlete-controlled). Methods: In a randomised design, 15 male trained cyclists (age: 39 ± 8 years, body mass: 79.4 ± 8.2kg, VO2max: 59.8 ± 6.5 ml·kg⁻¹·min⁻¹, peak power: 436 ± 27 W) performed one incremental maximal exercise test, one familiarisation session and three experimental high-intensity interval sessions implementing one of three pacing strategies; (i) “all-out”, (ii) computer-controlled and (iii) athlete-controlled. All experimental sessions were work- matched and consisted of three 3-minute intervals with three minutes of recovery. A 4 km time trial was completed twenty minutes following each experimental interval session to assess measured levels of latent fatigue. Oxygen consumption, heart rate and perceived exertion, pain and effort were recorded throughout the high-intensity interval sessions with average power output and heart rate measured throughout
the 4 km time trial. **Results:** Overall greater (p<0.001) oxygen consumption was observed in the “all-out” condition (54.1 ± 6.6 ml.kg⁻¹.min⁻¹) compared with the computer- (51.5 ± 5.7 ml.kg⁻¹.min⁻¹) and athlete-controlled conditions (53.0 ± 5.8 ml.kg⁻¹.min⁻¹). Furthermore, the time spent at 85% VO₂max was greater (p<0.001) during the “all-out” trial when compared with computer- and athlete-controlled trials. Sessional perceived exertion was greater in the “all-out” trial when compared with the computer- (p<0.001) and athlete-controlled (p<0.05) conditions. Average power output measured during the 4 km time trial was lower (p<0.001) after the “all-out” session compared with both even-pacing strategies. **Conclusion:** Our findings indicate irrespective of work completed, greater physiological stress was observed within an “all-out” interval training approach when compared with both athlete- and computer- controlled conditions, resulting in greater latent fatigue as measured by 4 km time trial performance. The selections of pacing strategies are likely to play a key role in interval training and should be acknowledged throughout exercise prescription.
DEFINITION OF TERMS

For consistency of interpretation the preceding words are defined:

**Active recovery:**
Low-intensity exercise completed between interval repetitions.

**“All-Out”:**
A maximal acceleration produced over a set period of time with a higher power output at the beginning of an exercise/interval session.

**Athlete-controlled:**
Pacing selection internally controlled via the manipulation of gear ratio and cadence to achieve a nominated power output.

**Computer-Controlled:**
Pacing selection with a fixed power output externally controlled for a predetermined period of time.

**High-Intensity interval training:**
Physical exercise that is characterized by brief, intermittent bursts of vigorous activity, interspersed by periods of rest/low-intensity exercise.

**Interval training:**
Repeated bouts of vigorous exercise interspersed with recovery periods.
ABBREVIATIONS

Selected abbreviations used throughout the text

ANOVA: analysis of variance
AO: “all-out”
CT: continuous training
dw: dry weight
HIT: High-intensity interval training
HR$_{\text{max}}$: maximum heart rate
km: kilometer
min: minute
PGC-1α: peroxisome-proliferator activated receptor y co-activator
PPO: peak power output
REP: repetitions
s: second
TT: time trial
Ve BTPS: expired ventilation body temperature and pressure saturation
VT$_1$: ventilatory threshold one
W: watt
wk: week

AC: athlete-controlled
CC: computer-controlled
D: day
EVA: exposure variation analysis
HR: heart rate
kJ: kilojoule
m: meter
mmol/L: millimoles per litre
P$_{\text{max}}$: power associated with maximal aerobic capacity
PTS: peak treadmill speed
RPE: rating of perceived exertion
T$_{\text{max}}$: time associated with maximal aerobic capacity
VAS: visual analogue scale
VO$_{\text{2max}}$: maximal aerobic capacity
VT$_2$: ventilatory threshold two
W:R: work to rest ratio