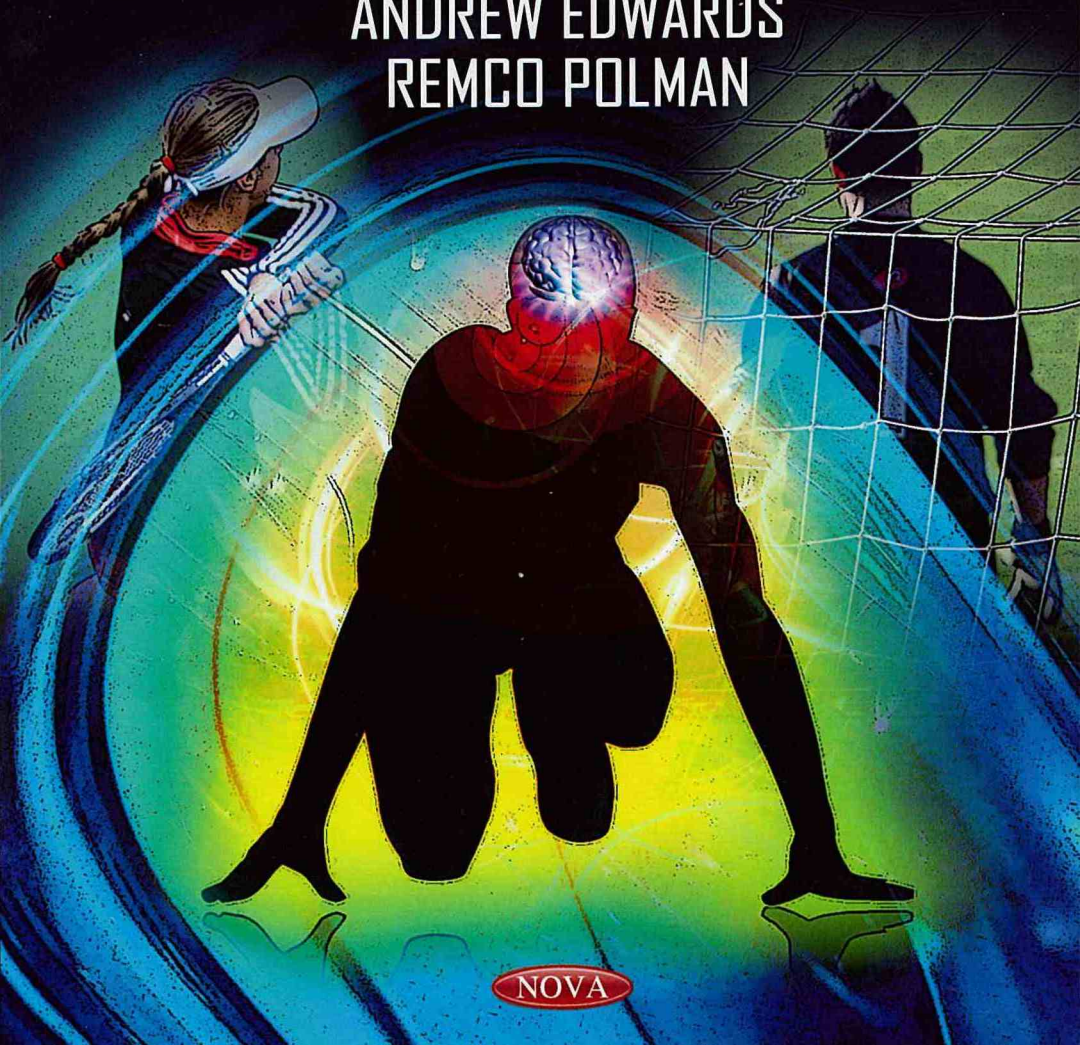


SPORTS AND ATHLETICS PREPARATION, PERFORMANCE, AND PSYCHOLOGY

PACING IN SPORT AND EXERCISE

A Psychophysiological Perspective

ANDREW EDWARDS
REMCO POLMAN



NOVA

**SPORTS AND ATHLETICS PREPARATION,
PERFORMANCE, AND PSYCHOLOGY**

**PACING IN SPORT
AND EXERCISE:
A PSYCHOPHYSIOLOGICAL
PERSPECTIVE**

SPORTS AND ATHLETICS PREPARATION, PERFORMANCE, AND PSYCHOLOGY

Additional books in this series can be found on Nova's website
under the Series tab.

Additional E-books in this series can be found on Nova's website
under the E-book tab.

**SPORTS AND ATHLETICS PREPARATION,
PERFORMANCE, AND PSYCHOLOGY**

**PACING IN SPORT
AND EXERCISE:
A PSYCHOPHYSIOLOGICAL
PERSPECTIVE**

**ANDREW EDWARDS
AND
REMCO POLMAN**



Nova Science Publishers, Inc.
New York

Copyright © 2012 by Nova Science Publishers, Inc.

All rights reserved. No part of this book may be reproduced, stored in a retrieval system or transmitted in any form or by any means: electronic, electrostatic, magnetic, tape, mechanical photocopying, recording or otherwise without the written permission of the Publisher.

For permission to use material from this book please contact us:

Telephone 631-231-7269; Fax 631-231-8175

Web Site: <http://www.novapublishers.com>

NOTICE TO THE READER

The Publisher has taken reasonable care in the preparation of this book, but makes no expressed or implied warranty of any kind and assumes no responsibility for any errors or omissions. No liability is assumed for incidental or consequential damages in connection with or arising out of information contained in this book. The Publisher shall not be liable for any special, consequential, or exemplary damages resulting, in whole or in part, from the readers' use of, or reliance upon, this material. Any parts of this book based on government reports are so indicated and copyright is claimed for those parts to the extent applicable to compilations of such works.

Independent verification should be sought for any data, advice or recommendations contained in this book. In addition, no responsibility is assumed by the publisher for any injury and/or damage to persons or property arising from any methods, products, instructions, ideas or otherwise contained in this publication.

This publication is designed to provide accurate and authoritative information with regard to the subject matter covered herein. It is sold with the clear understanding that the Publisher is not engaged in rendering legal or any other professional services. If legal or any other expert assistance is required, the services of a competent person should be sought. FROM A DECLARATION OF PARTICIPANTS JOINTLY ADOPTED BY A COMMITTEE OF THE AMERICAN BAR ASSOCIATION AND A COMMITTEE OF PUBLISHERS.

Additional color graphics may be available in the e-book version of this book.

LIBRARY OF CONGRESS CATALOGING-IN-PUBLICATION DATA

Pacing in sport and exercise : a psychophysiological perspective / Andrew Edwards and Remco Polman , editors.

p. cm.

Includes index.

ISBN 978-1-61942-420-3 (hardcover)

1. Sports--Psychological aspects. 2. Sports--Physiological aspects. 3. Cardiac pacing. 4. Endurance sports. I. Edwards, Andrew. II. Polman, Remco.

GV706.4.P335 2011

796.01--dc23

2011047268

Published by Nova Science Publishers, Inc. / New York

For all my friends and family who have supported me over the years. In particular this is for my wife Tracy, son Alex and father Harry Edwards.

Andrew

To my mother for all her love and support throughout my life.

Remco

CONTENTS

List of Figures	vii	
List of Tables	xi	
Foreword	xv	
Preface	xvii	
Acknowledgments	xxi	
Author Biographies	xxiii	
Chapter 1	Evolution of Training and Performance	1
	1.1. Abstract	1
	1.2. Introduction	1
	1.3. Evolution of Human Athletic Performance	2
	1.4. Evolution of Training Methods	6
	1.5. The Challenge of Sustaining Progress	15
	Conclusion	18
	References	19
Chapter 2	An Introduction to Pacing in Sport and Exercise	23
	2.1. Abstract	23
	2.2. Introduction	23
	2.3. The Concept of Pacing	24
	2.4. The Origins of Paced Activity	27
	2.5. Psychology of Pacing	31
	2.6. Performance and Pacing Strategy	34
	Conclusion	41
	References	42

Chapter 3	Limitations to Physical Performance	49
	3.1. Abstract	49
	3.2. Introduction	49
	3.3. The Nervous System	50
	3.4. Limitations: Central and Peripheral Observations	53
	3.5. Limitations: Cardiovascular Regulation	55
	3.6. Limitations: Brain Regulation	58
	3.7. Limitations: Psychological Considerations	65
	Conclusion	69
	References	70
Chapter 4	Monitoring and Self-Regulating Training	77
	4.1. Abstract	77
	4.2. Introduction	77
	4.3. Methods to Monitor Training Outcomes	78
	4.4. Self-Regulatory Training Skills	87
	Conclusion	95
	References	95
Chapter 5	Pacing for Endurance	99
	5.1. Abstract	99
	5.2. Introduction	99
	5.3. Physiology of Endurance	100
	5.4. Psychology of Endurance	105
	5.5. Pacing and Strategy for Endurance	109
	5.6. Self-Regulatory Training for Endurance	114
	5.7. Athlete Comment: Endurance	123
	Conclusion	124
	References	125
Chapter 6	Pacing for Power, Strength and Speed	131
	6.1. Abstract	131
	6.2. Introduction	131
	6.3. Physiology of Anaerobic Exercise (Power, Strength and Speed)	132
	6.4. Psychological Aspects of Pacing for Power, Strength and Speed	134
	6.5. Pacing for Power, Strength and Speed	136
	6.6. Self-Paced Anaerobic Training	140
	6.7. Athlete Comment: Power, Strength, Speed	150

	Conclusion	150
	References	151
Chapter 7	Pacing for Team Sports	157
	7.1. Abstract	157
	7.2. Introduction	157
	7.3. Match Demands	158
	7.4. Pacing for Team Sports	160
	7.5. Preparatory Psychological Skills for Team Sports	165
	7.6. Training for Team Sports	167
	7.7. Practitioner Comment: Team Sports	177
	Conclusion	178
	References	178
Chapter 8	Pacing for Special Populations	183
	8.1. Abstract	183
	8.2. Introduction	183
	8.3. Children and Pacing	184
	Conclusion	194
	References	195
Index		201

LIST OF FIGURES

Figure 1.1a (male) and 1.1b (female). Progression of male and female world record performances across selected track and field events	3
Figure 1.2. Evolution of training periodization from the Greek <i>tetrad</i> to modern periodization.....	9
Figure 1.3. Principles of overload whereby performance in response to each cyclic period of training (mesocycle) results in fatigue and subsequent adaptation and progressive performance gain	13
Figure 1.4. An example of outcomes for training volume and intensity in response to nonlinear periodization resistance training.....	14
Figure 2.1a and 2.1b. The agony (800m) and ecstasy (1500m) of Sebastian (Lord) Coe vs. Steve Ovett at the 1980 Olympic games	24
Figure 2.2. Humans and Cheetahs: both exhibit pacing behaviours in response to the known demands of a task	30
Figure 2.3. Average lap times (s) for 32 world record mile performances between 1880 and 1999.	37
Figure 2.4. Six commonly observed pacing strategies.	39
Figure 3.1. Brain regulation of human movement in response to afferent and efferent signals.....	50
Figure 3.2. Mechanism of fatigue according to AV Hill's (Cardiovascular/Anaerobic) Model of Exercise Physiology	56

Figure 3.3. Example of oxygen uptake ($\dot{V}O_2$) responses to two maximal incremental exercise challenges.	59
Figure 3.4. Brain regulation of performance based on feedback (afferent) signals from different physiological systems and feedforward (efferent) signals to muscle	61
Figure 3.5. A comparison of brain regulation models of human movement.....	64
Figure 3.6. Negative sensations such as metabolic acidosis develop in severity as exercise becomes progressively challenging	68
Figure 4.1. the CR10 Borg Rating of Perceived Exertion scale	85
Figure 4.2. An RPE-based system for monitoring responses and performance outcomes from a training programme	86
Figure 5.1. Summary of the main pathways of energy metabolism using carbohydrate and lipids as energy sources.....	101
Figure 5.2. Average speeds (m/s) (\pm SD) for swimming stage of the Lausanne 2002 ITU World Cup triathlons (n=68 males).....	112
Figure 5.3. Speed (average \pm S.E. (km/h) over each bike lap of ITU male Triathlon by pack number to which the athletes belonged (5 packs)...	112
Figure 5.4. Run speed (\pm S.E) for three packs of ITU World Cup male triathlon competitors.	113
Figure 5.5. Race pace profiles comparing on-water (n = 948) and ergometry (n = 170) trials.	114
Figure 6.1. Pacing of 1000m sprint performance in speed skating in experienced men and women	137
Figure 6.2. Power output in response to 30s Wingate testing, either with or without motivational music.	139
Figure 6.3. Rating of perceived exertion (RPE) values at 50, 70, and 90% of 1 repetition maximum.	141
Figure 6.4. One repetition maximum (1RM) strength across leg press and chest press exercise both with and without a personal trainer being present.....	143

Figure 7.1. Multi level model of pacing in team sports	162
Figure 7.2. An example of soccer match-play pacing strategy in operation with permission [3].	164

LIST OF TABLES

Table 1.1. Progression of selected world track and field records from 1900 to 2011	4
Table 4.1. A comparison of heart rate TRIMP outcomes for three training sessions and their accumulated score as an indicator of cyclic training load.....	81
Table 4.2. Heart rate zone TRIMP [3]. This system allocates average heart rates into zones for subsequence TRIMP calculation (duration x zone).....	82
Table 4.3. Summary of selected self-regulatory training skills. Many of these skills inter-relate.....	94
Table 5.1. Preliminary profiling of interval (Int) training sessions for endurance athletes (duration x RPE).....	118
Table 5.2. Preliminary profiling of all continuous-run session options.	119
Table 5.3. Preliminary profiling of all resistance training sessions	119
Table 5.4. The example of a training schedule drawing on sessions identified from Tables 1-3 by the coach for implementation (endurance)	121
Table 5.5. Benchmarked descriptors and evaluation of training load (endurance).....	122
Table 5.6. Athlete's weekly self evaluation and coping self assessments in relation to training load (endurance).....	122

Table 6.1. Preliminary profiling of interval training sessions (power, strength, speed).....	146
Table 6.2. Preliminary profiling of continuous-run sessions (power, strength, speed).....	147
Table 6.3. Preliminary profiling of resistance training sessions (power, strength, speed).....	147
Table 6.4. The training schedule and system for monitoring training load (power, strength, speed).....	148
Table 6.5. Benchmarked descriptors and evaluation of training load (power, strength, speed).....	149
Table 6.6. Weekly training load (taken from table 4) and description, coupled with the athlete's self assessment of coping (power, strength, speed).....	149
Table 7.1. A summary of characteristics within the multi-level pacing model in elite team sport activities.....	162
Table 7.2. Preliminary profiling of interval training (Int) sessions (team sports)	172
Table 7.3. Preliminary profiling of small-sided games (SSG) (team sports)	173
Table 7.4. Preliminary profiling of skill-based training (SBT) (team sports)	173
Table 7.5. Preliminary profiling of continuous-run sessions (CON) (team sports)	174
Table 7.6. Preliminary profiling of strength and conditioning (SCT) (team sports)	174
Table 7.7. Match-play situations.....	175
Table 7.8. The training schedule and system for monitoring training load during the pre-season period of training (8 week programme) (team sports).	175
Table 7.9. Benchmarked descriptors and evaluation of training load (team sports).	176

Table 7.10. Weekly training load and description, coupled with the athlete's self assessment of coping (team sports)	176
--	-----

FOREWORD

Pacing is one of the most important concepts in sport and exercise. The regulation of effort is a choice that every athlete and exerciser must make continuously (if not always with awareness) throughout every workout and competition, and this choice has a profound effect on outcomes. The difference between successful and unsuccessful pacing is often the difference between achieving and falling short of goals; between benefiting and failing to benefit from the work that is done.

Athletes, coaches, exercisers, and trainers have long recognized the importance of pacing and employed experience-based strategies and methods to teach and practice successful pacing. But until recently pacing received relatively little attention from exercise scientists. There was a tendency to view pacing as a psychological phenomenon and therefore outside the purview of mainstream exercise science, whose focus has always been physiological. Inasmuch as pacing *was* studied, it was studied from a physiological perspective that tended to “explain away” the obvious psychological dimension of the phenomenon.

Recent advances in our knowledge of the brain have lately brought long overdue attention to pacing in the exercise science community. There is a growing recognition that pacing is a phenomenon with both psychological and physiological dimensions that are deeply mutually interpenetrating. Improvements in our understanding of how the exercise pacing mechanism really works are opening up exciting new possibilities for the practice of effective pacing in sport and exercise. A need has therefore emerged for a comprehensive and authoritative resource that summarizes what we now know about exercise pacing and more fully realizes the potential for practical

application of this new knowledge for a broad audience of scientists, coaches, trainers, athletes, and exercisers.

Andrew Edwards and Remco Polman have met that need masterfully with this book. *Pacing in Sport & Exercise* presents a cogent and compelling explanation of pacing that, while certainly not representing the last word on the subject, is as close as anyone has yet come. On the solid foundation of their persuasive model the authors have constructed a perception-based system of monitoring and controlling pace, as well as of quantifying and controlling training loads that is easy to comprehend and apply, whether you're a football coach or a beginning jogger seeking weight-loss.

The bias toward physiology and technology that has dominated sport training and exercise prescription for many decades has discouraged people from developing the refined sense of effort perception, the trust in such perception, and particular psychological tools without which optimal pacing is not possible. *Pacing in Sport & Exercise* holds the promise to correct this imbalance with a single stroke, and I expect it to have a revolutionary effect in a wide range of sports and exercise modalities.

For me personally, Edwards and Polman's book fills a big hole that was left open in my own efforts to help endurance athletes conceptually tie mind and body together and become better pacers, hence better racers—most notably in my books *Brain Training for Runners* and *RUN: The Mind-Body Method of Running by Feel*. I intend to rely heavily on Edwards and Polman's invaluable new contribution to the field in my future work as a writer and coach, and I know I will not be alone.

Matt Fitzgerald
San Diego, California, USA

PREFACE

The study of pacing is a relatively new and exciting area of investigation, owing much to original studies by leading academics such as Professors Carl Foster, Veronique Billat and Tim Noakes. These researchers, among others, have demonstrated that pacing is not simply a muscle-driven outcome of performance; it is an important regulatory process that determines performance. Yet, the concept of pacing is not merely confined to elite performance; it underlies all human movements in which voluntary effort is required. As such, the mechanisms by which we regulate pace are complex, requiring mind-body interaction. Therefore, we have considered this topic from a psychophysiological perspective.

Pacing in Sport and Exercise: A Psychophysiological Perspective is, to our knowledge, the first book which comprehensively examines the way humans pace exercise and sporting activities. Research on pacing has been dominated by physiological investigations despite the acknowledgement by many authors on the interdisciplinary nature of pacing. Therefore, we consider both physiological and psychological influences on pacing, before developing an interdisciplinary perspective. This approach explains metabolic regulation during exercise and also facilitates the development of a practical (self-regulatory) means with which to optimise training.

Chapter one of this book provides an overview of the factors associated with the evolutionary development of human athletic performance. It presents a historical view on human training and conditioning perspectives and also on methods including the use of linear and non-linear periodization systems. Chapter two introduces the concept of pacing in sport and exercise. We define pacing as '*the goal directed distribution and management of effort across the duration of an exercise bout*'. Evidence from both animal and human studies is

presented to illustrate the way species adapt behaviour to contextual and personal constraints and pace activities accordingly.

A guiding principle is to see pacing as a neural buffering process preventing premature physical exhaustion. In chapter three, both physical and psychological limitations to human performance are discussed. Limitations of traditional physiological models and also the contemporary central governor model of metabolic control are outlined. We propose a new '*conscious brain regulation*' model as a variation to the central governor model, which provides a simpler but more comprehensive explanation of the many phenomena associated with pacing and fatigue in sport and exercise from a psychophysiological perspective. In chapter four, self-regulatory systems for developing skills and also for monitoring training outcomes are identified and discussed. In particular, the rate of perceived exertion (RPE) for monitoring training is suggested as a practical way of both setting and monitoring training across all modes of exercise. The facilitating and debilitating role of psychological factors like mental toughness, coping strategies and self-confidence are also discussed. Pacing in relation to endurance activities is explored in chapter five. The physiological and psychological demands of activities like marathon running, cycling, rowing and triathlon are outlined. Although the ability to sustain high rate of work output continuously over time is important, from a strategic perspective, front loaded, fast start pacing appears to be optimal for most endurance events. Also, associative coping strategies appear to be related to better performance outcomes in high performance athletes. This chapter provides the reader with a practical example of setting and monitoring endurance training using an example of a RPE-based training programme allowing adoption of an individualised training load.

Although the role of pacing may not be intuitively apparent for power, strength and speed events, in chapter six we provide the reader with information on the relevance of appropriate pacing strategies across anaerobic events. High intensity activities might also benefit from preparatory strategies to control arousal levels or expectancies. This chapter also contains a self-paced system and practical example for training in power, strength and speed activities. In chapter seven, pacing for team (invasion-type) sports is discussed. Most team sports are intermittent in nature requiring utilization of both aerobic and anaerobic energy systems. Pacing strategies are apparent in team games, yet are more complex as energetic demands vary by position and the game situation. A multi-level pacing model is discussed based on observations in soccer, yet which is applicable to all invasion games. A

practical example of self-regulatory training for team sports is provided. Finally, in chapter eight we outline a number of situations in which self-regulation of exercise might need to be accompanied by other extrinsic (support) techniques. For example, accuracy of self-perception is less developed in children because of their inexperience and can also be distorted among all individuals when homeostasis is compromised by illness or medication. The regulation of exercise behaviour in children, in individuals with Multiple Sclerosis and the obese are examined.

ACKNOWLEDGMENTS

The authors would like to thank friends, colleagues and family for all their help, advice and assistance with preparing and proof reading this book. Tracy Edwards (MSc, Oxford) patiently led the proof reading process and for this we are very grateful. Erika Borkoles (PhD, Hull) provided much appreciated assistance and additional perspective.

As inspiration, we would like to acknowledge Professor Tim Noakes who, in our opinion, remains the undisputed champion of exercise physiology. For Matt Fitzgerald, we greatly appreciate his foreword to this book and his meaningful contributions to the literature which promote self-regulatory exercise via a collection of books.

AUTHOR BIOGRAPHIES

Andrew M. Edwards BEd (Hons 1), MPhil, PhD

Andrew Edwards gained a PhD in Exercise Physiology from Sheffield Hallam University in December 2003 and has since worked as an academic in the UK, New Zealand and Australia. He is a British Association of Sport & Exercise Sciences (BASES) accredited scientist and is the Director of the Institute of Sport & Exercise Science (ISES) at James Cook University, Cairns, Australia. Andrew's main research interest is the inter-relationships between fatigue, pacing and high performance sport. He has written many original research articles and worked as a consultant to several professional UK soccer clubs.

In addition to his academic achievements, Andrew is a former UK nationally ranked 400m hurdler and elite level rower/sculler. He competed at many national events in both sports, such as the AAA athletics championships and Henley Royal Regatta. In recent years he won the 400m and 400m hurdles at the New Zealand and Pan Pacific Masters games respectively. He is committed to examining theory-practice interaction in sport and exercise science.

Contact details: andrew.edwards@jcu.edu.au

Professor Remco Polman DPhil, CPsychol, AFBPsS, Csci

Remco Polman's initial training was in the Faculty of Human Movement Sciences at the 'Vrije Universiteit', Amsterdam, The Netherlands where he

gained a 'Doctorandus' qualification (1992). Following this, he completed a PhD degree at the University of York, England.

Prior to commencing his current post as Professor and Research Leader in Active Living at Victoria University (Melbourne, Australia), Remco was Professor of Sport and Exercise Sciences and Director of the Centre of Applied Sport and Exercise Science at the University of Central Lancashire, Preston UK. He is a chartered psychologist by the British Psychological Society (BPS) and an accredited sport and exercise psychologist by the Health Professions Council in the UK. He is also accredited for psychological research by BASES and for practice, research and teaching by the Dutch Association of Sport Psychology (VSPN). Remco has fulfilled a number of roles with the Division of Sport and Exercise Psychology (DSEP) of the BPS, including chair, chair elect and honorary secretary. His research interests are diverse and include stress, coping and emotions in sport and exercise, the psychology of (sport) injury rehabilitation; personality and sport and exercise (Mental toughness, Type D personality), exercise psychology (special populations, exercise prescription) and ageing (interaction between psychological and biomechanical factors).

Contact details: Remco.Polman@vu.edu.au