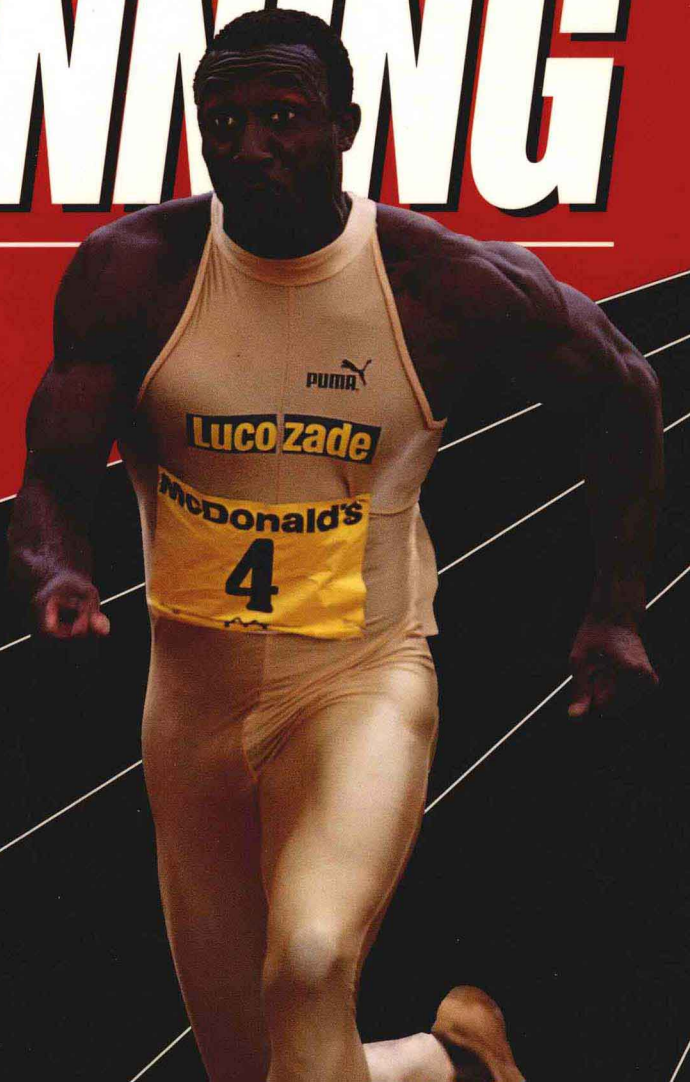
Eric Newsholme • Tony Leech • Glenda Duester

KEEP ON RUNNING

The Science of Training and Performance



WILEY
Publishers Since 1807

Keep on Running

The Science of Training and Performance

Eric Newsholme

Department of Biochemistry, University of Oxford and Merton College, Oxford, UK

Tony Leech

Gresham's School, Holt, Norfolk, UK

Glenda Duester

Department of Biochemistry, University of Oxford, UK

JOHN WILEY & SONS

Chichester · New York · Brisbane · Toronto · Singapore

Reprinted November 1994

Other Wiley Editorial Offices

John Wiley & Sons, Inc., 605 Third Avenue,
New York, NY 10158-0012, USA

Jacaranda Wiley Ltd, G.P.O. Box 859, Brisbane,
Queensland 4001, Australia

John Wiley & Sons (Canada) Ltd, 22 Worcester Road,
Rexdale, Ontario M9W 1L1, Canada

John Wiley & Sons (SEA) Pte Ltd, 37 Jala Pemimpin #05-04,
Block B, Union Industrial Building, Singapore 2057

Library of Congress Cataloging-in-Publication Data

Newsholme, E. A.
Keep on running : the science of training and performance / Eric Newsholme, Tony Leech, Glenda Duester.
p. cm.
Includes bibliographical references (p.) and index.
ISBN 0 471 94313 4 (cloth)—ISBN 0 471 94314 2 (pbk)
1. Running—Training. 2. Running—Physiological aspects.
I. Leech, A. R. II. Duester, Glenda. III. Title.
GV1061.5.N49 1993
796.42—dc20 93-49630
CIP

British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

ISBN 0 471 94313 4 (cloth)
ISBN 0 471 94314 2 (paper)

Typeset in 10/12pt Century Schoolbook by
Acorn Bookwork, Salisbury, Wilts
Printed and bound in Great Britain by Redwood Books, Trowbridge, Wiltshire

Authors

Eric Newsholme, M.A., Ph.D., D.Sc., is a Reader in Cellular Nutrition, at the Department of Biochemistry, University of Oxford, UK. He is an experienced marathon runner, having participated in 37 marathons. Dr Newsholme is co-author of *Regulation in Metabolism* (Wiley 1973), *Biochemistry for the Medical Sciences* (Wiley 1983), *The Runner* (Fitness Press, USA, 1983) and numerous research papers.

Tony Leech, M.A., D.Phil., is a biology teacher at Gresham's School, Holt, UK. He is co-author of *Biochemistry for Medical Sciences* (Wiley 1983) and *The Runner* (Fitness Press, USA, 1983).

Glenda Duester, B.A., M.Sc., is a research assistant in biochemistry at the University of Oxford, UK. She is a club marathon and half-marathon runner.

Bruce Tulloh, Ph.D., was the gold medal winner at 5000 metres in the European Championships (1962). He is a biology master at Marlborough College, Wiltshire, UK and is currently coaching editor of *Runner's World.*

The foreword was kindly written by **Professor P.-O. Åstrand**, Emeritus Professor, Karolinska Institute, Stockholm and author with K. Rodahl of the classic *Textbook of Work Physiology.* He is a world authority on physical education and physiology and since he started in the field in 1946 is now a father figure of science in athletic performance.

Foreword

No other tissue in the human body can vary its metabolic rate so dramatically as skeletal muscle. In fact, active muscles can increase their oxidative processes to more than 50 times the resting level. Such an enormous variation in metabolic rate necessarily creates problems for muscle cells because, while consumption of oxygen and fuel (substrates) increases 50-fold, the rate of removal of produced heat, carbon dioxide, water and "waste products" must be similarly increased. To maintain the chemical and physical equilibrium within the body, there must be a tremendous increase in the exchange of molecules between the inside and outside of the muscle cells. When muscles are thrown into vigorous activity, the ability to maintain the internal equilibrium at a level permitting continuous exercise is entirely dependent on those organs that service the muscles. This dependence is especially true in the case of respiration and circulation, but certainly food intake, digestion and handling of substrates, kidney function, temperature regulation, water balance regulation and the effect of various hormones are also affected by variations in the metabolic rate caused by more or less intensive physical activity.

There is a definite tendency for new scientific frontiers like microbiology, genetics, immunology, developmental biology and neuroscience to dominate both in the award of research grants and in the teaching of medicine, medical science, biochemistry and biology. However, such emphasis on subject specialities by enthusiasts is not without risk. Other sectors of biology and medicine that may in the future become more important run the risk of being neglected. These risks have been emphasized by the American and British Physiological Societies. It is very important that physiologists and biologists convert the lifeless pieces of molecular and cellular biology into living systems.

In my opinion, "exercise physiology" is from these viewpoints particularly important because an exercise situation in various environments provides unique opportunities to study how different functions

of the body are regulated and integrated. As stated above, most functions and structures in the body are in one way or another affected by acute and chronic (i.e. training) exercises. Therefore, exercise physiology is to a high degree an integrated science that has as its goal the identification of the mechanisms of overall bodily function and its regulation. It is therefore regrettable therefore, that so few pages in standard textbooks in biochemistry and physiology for medical students are devoted to discussions of the effects of physical activity on different structures and functions.

Newsholme, Leech and Duester have written an excellent and highly needed example of a text that illustrates the importance of a broad, holistic approach when analysing human structures and functions. Walking and running are activities developed millions of years ago during evolution of the hominid family. We have been hunters and gatherers, i.e. nomadic people, during more than 99% of our existence as hominids! Therefore "service systems" securing an optimal internal environment, function and performance during walking and running were developed, modified and adapted. It is very logical to choose running when discussing human biochemistry and physiology because it is a situation in which cells and organs are following the Three Musketeer principle in their functional strategies: "All for one and one for all!" Running can stress the body and mind to its limit and it is important and fascinating to analyse limiting factors, risks of overload, prevention of such risks and treatment of the consequences of overload. These aspects of human athletic achievement have high priorities in this volume.

The text is highly educational and it will serve professional teachers in physiology and medicine. At the same time, the authors have successfully presented and discussed complicated scientific events in a fluent and didactic style so that it can be enjoyed and understood by athletes and general readers with no formal background in biochemistry and physiology. The only prerequisite is curiosity about the function of the human body and this curiosity should have a high priority.

Per-Olof Åstrand

Preface

Most people have a greater understanding of how their car works than how their body works, although this is less likely to be true for athletes, who, in the process of pushing their bodies to the limit, acquire much information about themselves. Many runners will have had little in the way of scientific education and need to work hard if they are to assimilate all the biochemical, nutritional, physiological and psychological information that is now available. The reward for this effort, however, is now considerable, with the real possibility of using the information to improve performance. But even if this were not so, knowledge of what is going on 'under the bonnet' can add greatly to the pleasure of running even for those of us who will gain no medals.

This book has been written for athletes, at any stage of their career, for coaches, for physicians and for anyone who wishes to understand more about the scientific basis of running. It is also intended to help students of sports science, especially those without a strong background in science. For the most part we have emphasized ideas rather than details and, where possible, have presented biochemistry without the equations and physiology without the mathematics.

Understandably the athlete has a muscle-centred view of his or her body and it is with muscles that we begin in Chapter 2. Human muscles can no more defy the laws of physics than can the internal combustion engine so to continue working they require a source of energy. How this is stored, made available and can limit performance in different events is described in the following chapters. To be used, these fuels and the oxygen needed for their combustion must reach the muscles, and an understanding of the body's supply lines, described in Chapter 7, has always been an important aspect of sports science. Although female participation in all track and road events is now accepted, the history of women's running is short and in Chapter 8 we consider some of the few ways in which female runners are different.

The modern holistic approach to training acknowledges that the body as a whole must be trained and that this includes the mind. Although our understanding of the scientific basis of behaviour lags far behind our physiological knowledge, the scientific approach is maintained in Chapter 10. In contrast, much more is known about the connection between diet and human energy metabolism and in Chapter 11 we explore these links, seeking to correct misconceptions and show how the athlete's dietary needs are somewhat different from those of the average person. It is an unfortunate fact that most athletes will have to endure some spell of injury during their career and in Chapter 12 we attempt to explain the nature of common injuries. Whereas dietary manipulations are an accepted part of race preparation, the use of drugs is not and in the final chapter of Part I we present some of the reasons for this.

Above all, we hope to have not lost sight of the practical application of science to running and in Part II offer specific advice, beginning with a set of training schedules for a whole range of distances which can be modified to suit individual requirements. Readers may be surprised to find recipes in a book on scientific principles but any runner trying to cope with the special demands of intense training schedules, and the problem of finding time to prepare satisfactory 'athletic meals', should find them very useful. Part II also contains advice on many other aspects of race preparation, from learning to relax to choosing a bra.

It is, of course, not possible to write a book of this kind without a great deal of help from others. Much of this has been garnered from the written page—that repository of shared knowledge characteristic of scientific endeavour. Many of our sources have been listed as 'Further Reading' but there are inevitably many other pieces of published work which we have made use of, consciously and unconsciously. We are particularly grateful to Craig Sharp and to Priscilla Clarkson, who commented so generously and helpfully on the manuscript and helped us to avoid at least some of the more embarrassing errors. Help with particular parts of the book was provided by C. Pond, Open University, T.F.R.G. Braun, Merton College and J.A.N. Railton, Oxford University Committee for Sport. We would also like to thank the typists who have been involved with the preparation of this book, particularly Judith Kirby and Shirley Greenslade. We thank Brian Taylor, librarian of the Department of Biochemistry, University of Oxford, for his help in obtaining books and journals to aid our access to the information, so that we had more time for preparation of the book. We also thank Stanley Greenberg, honorary statistician to the British Athletic Federation and BBC TV Athletic Statistican for

provision of information on current British, Olympic and World records for track and field athletic events and the marathon.

Finally we thank our families for their patience and support during the long periods of writing and preparation of the book.

Contents

Authors xi
Foreword xiii
Preface xv

Part I Running Principles 1

1. Running In 3
TRAINING: A HISTORICAL PERSPECTIVE 7
THE SCIENTIFIC APPROACH 11

2. Muscles and Movement 19
GETTING MOVING 20
MUSCLES FOR RUNNING 21
CONTROLLING THE CONTRACTIONS 27
TAKING A MICROSCOPE TO MUSCLE 34
STRENGTH, SPEED AND ENDURANCE 40
DIFFERENT MUSCLES FOR DIFFERENT TASKS 47

3. Energy Matters 50
HOW MUCH ENERGY? 50
ENERGY IN ALL ITS GUISES 54
ATP: BIOLOGICAL ENERGY INTERMEDIATE 63

4. Filling the Fuel Tanks 70
THE PERFECT STORAGE FUEL 70
GLYCOGEN: PACKAGED GLUCOSE 72
TRIGLYCERIDE: CONCENTRATED ENERGY 74
MAKING THE FUELS AVAILABLE 80
GENERATING ATP 84
A MATTER OF CONTROL 86
MANAGING WITHOUT OXYGEN 86
PHOSPHOCREATINE: SHORT-TERM BOOST 90

5. Fuel Management 95
100 METRES 96
200 METRES 100

400 METRES 100
MIDDLE DISTANCES: 800 METRES AND 1500 METRES 102
LONG-DISTANCE TRACK EVENTS: 3–10 KILOMETRES 105
MARATHON AND ULTRA-MARATHON 107

6. When the Running Has to Stop 113
FATIGUE AND PHOSPHOCREATINE 114
AVOIDING AN ACID BATH 116
THE MIDDLE-DISTANCE BALANCING ACT 122
THE MARATHON 123
FATIGUE AND BLOOD GLUCOSE 125
FATIGUE AND AMINO ACIDS 127

7. Maintaining the Supply Lines 131
THE HEART OF THE SYSTEM 131
CAPILLARY ACTION 135
DISTRIBUTING THE BLOOD 137
CONTROLLING THE SYSTEM 142
PUMPING IRON 145
OVERHEATING 149
ENVIRONMENTAL INTERFACE 151
VITAL AND OTHER CAPACITIES 152

8. The Female Runner 158
GETTING IN ON THE ACT 159
RUNNING FOR ALL 160
WOMEN: A RACE APART? 161
UNDERSTANDING THE CYCLE 166
ATHLETICS AND THE CYCLE 170
DISORDERED EATING 173
THE PREGNANT RUNNER 175

9. Theory into Practice 177
LIMITING FACTORS 179
TRAINING FOR ANAEROBIC PERFORMANCE 180
Training on the Track 181
Weight-Training 181
IMPROVING AEROBIC CAPACITY 182
Short Intervals (below 400 m) 182
Long Intervals (0.5–2 km) 187
Longer Distances (3–20 km) 189
Very Long Distances (30 km+) 189
Hill-Training 189
Altitude Training 190
Swimming and Pool Running 190
ROUNDING OFF 191
Other Muscles 191
Flexibility Training 191
TIMING IT RIGHT 192
Training Seasons 192
Conditioning 194

Pre-competition Training 194
Competition Training (Peak Training) 194

10. The Mind and Performance 198
OUR BEHAVIOUR 199
THE ATHLETE'S MIND 200
Improving the Inverted-U 202
EXPLAINING AROUSAL 204
FINDING OUT ABOUT ME 206
ARE ATHLETES DIFFERENT? 207
TRAINING TECHNIQUES 208

11. Food for Fitness 213
THE CARBOHYDRATES: SIMPLE AND COMPLEX 215
WHAT ABOUT THE ATHLETE? 219
GLYCOGEN LOADING 226
THE FATS: HIGH ENERGY BUT. . . 227
DOWN TO ESSENTIALS 231
THE PROTEINS: VARIATIONS ON AN AMINO ACID THEME 234
THE VITAMINS: THE ESSENTIAL ALPHABET 240
THE MINERALS: LIFE'S ADDITIONAL ELEMENTS 246
Calcium 247
Copper 249
Chromium 249
Iron 250
Magnesium 251
Selenium 251
Zinc 251
THE ELECTROLYTES: TOPPING UP THE BATTERY 252

12. When Training Goes Wrong 253
STRUCTURAL DAMAGE 254
Bone Injuries 254
Cartilage Problems 255
Ligament Injuries 256
Muscle Injuries 257
Tendon Injuries 257
Skin Injuries 258
Cramp and Stitch 259
INJURY AND HEALING 259
The Healing Process 260
RICE (ICER) FOR FIRST AID 261
Killing the Pain 262
CALL IN THE PHYSIO! 263
Massage 263
Stretching 264
Exercise 264
Strapping and Support 264
Heat 264
Electrotherapy 265

Cold Therapy 265
Prevention is Better than Cure 266
OVERTRAINING: TOO MUCH OF A GOOD THING 266
Diagnosis 269
Treatment 273

13. Dying to Win: Drugs and the Athlete 275
STIMULANTS 280
BETA-BLOCKERS 285
NARCOTIC ANALGESICS 288
ANABOLIC STEROIDS 288
DIURETICS 290
GROWTH HORMONE 291
BLOOD-DOPING 292
BLOOD-DOPING WITHOUT THE BLOOD 294

Part II Principles into Action 295

A. Tulloh's Training Schedules 297
EXAMINING YOURSELF 297
PLANNING YOUR STRATEGY 298
CONSTRUCTING THE SCHEDULES 299
THE SCHEDULES IN GENERAL 300
DETAILS OF EXERCISES 346
[A] Loosening Exercises 346
[B] Stretching Exercises 346
[C] Strengthening Exercises 346
[D] Resistance Running 346
[E] Weight-Training 347
[F] Recuperation Running 347
[G] Differentials 347

B. Advice for Women Runners 348
CLOTHING 348
Underwear 348
Shorts 348
Overdressing 349
MENSTRUATION 349
PREGNANCY 349

C. Psychological Self-Assessment and Training 352
SPORTS EMOTIONAL REACTION PROFILE 352
DETERMINE YOUR SERP 353
LEARN TO RELAX 359
IMPROVE YOUR CONCENTRATION 361

D. The Runner's Diet 363
KEEPING UP THE CARBOHYDRATES 363
THE PROBLEM WITH FAT 365
OUR MENUS 366

E. Noakes' Advice on Injuries and Running Shoes **404**
INJURIES 404
THE FOOT 407
THE RUNNING SHOE 409
Outer Sole 409
Midsole 409
Slip or Board Lasting 410
Heel Counter 410
Straight or Curved Lasting 410

F. Medicines to Avoid **411**
DRUG NAMES 411
POINTS TO NOTE 411
BANNED SUBSTANCES 412

Further Reading and Bibliography **415**
Records **427**
Index **433**

Part I

Running Principles

Chapter 1

Running In

And it is right that in your Congress here you should study the 'making of a champion', *if I may borrow the title of the monumental book written here at Laval University. It is right that you should study the making of a champion, but it is also right that you should fulfil another and a greater task. Two centuries ago, the French Revolution gave us the concept of the rights of man. A century later, a great French statesman, Baron Pierre de Coubertin, added another right to those demanded by Jean-Jacques Rousseau and Robespierre; he added the right to play, to physical education, to unity of mind and body, to education in the Hellenic Gymnasium and in the playing fields. Baron de Coubertin not only created the Olympic Games, the magnificent assembly of the great élite, he propounded, first and lively to all mankind, the policy of sport for all.*

From a speech by Philip Noel-Baker, Director General of UNESCO, at the opening ceremony of an International Congress of Physical Activity Sciences in 1976 in Quebec City, prior to the Olympic Games in Montreal. Philip Noel-Baker won the silver medal in the 1500 m event at the Antwerp Olympic Games in 1920.

For many animals the ability to survive depends on ability to run, either from danger or to capture food; and human beings have most certainly survived for they are not only good runners but also versatile ones. This ability is still to be seen in modern times although we rarely have to run for survival. In the 1988 Olympic Games Carl Lewis won the gold medal in the 100 m, running at 43 km/h, and Gelindo Bordin won the marathon (42.195 km) in 2 h 10 min 32 s. In 1989 Tony Rafferty covered 1000 miles on the track in 14 days 11 h 59 min. These athletes were running not for survival but for pleasure—the pleasure of competing and the pleasure of winning. Many more men and women gain pleasure from maintaining their bodies in an optimal state of fitness, indeed the running 'high' has been likened to a state of drug-induced euphoria. Such pleasures are not new; two and a half thousand years ago professional Greek athletes, with their professional coaches, competed in organized competition for rich rewards.

Competition implies training—techniques and behaviour practised to improve performance. For, in contrast to machines, which begin to