OLYMPIC TEXTBOOK OF MEDICINE IN SPORT

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Contents

List of Contributors, vii
Foreword, x
Preface, xi

1 General Principles of Training, 1
MICHAEL I. LAMBERT, WAYNE VILJOEN, ANDREW BOSCH, ALAN J. PEARCE AND MARK SAYERS

2 Adaptations to Training, 49
Introduction, 49
IÑIGO MUJIKA
Models of fatigue, 49
SHONA HALSON AND IÑIGO MUJIKA
Neuromuscular adaptations to training, 67
NICHOLAS A. RATAMESS AND MIKEL IZQUIERDO
Metabolic adaptations to training, 78
JOHN A. HAWLEY AND GUSTAVO A. NADER
Endocrine adaptations to training, 87
MICHAEL KEIR, SIMON DOESSING AND KATJA PELTOLA MJOSUND
Cardiorespiratory adaptations to training, 93
DARREN E.R. WARBURTON, A. WILLIAM SHEEL AND DONALD C. MCKENZIE
Adaptations of bone and connective tissue to training, 111
PEKKA KANNUS, RIKU NIKANDER, HARRI SIEVÄNEN AND IÑIGO MUJIKA

3 The Overtraining Syndrome: Diagnosis and Management, 138
ROMAIN MEEUSEN

4 Clinical Exercise Testing and Assessment of Athletes, 160
ROBERT U. NEWTON, PAUL B. LAURSEN AND WARREN YOUNG

5 Clinical Myology in Sports Medicine, 200
WAYNE E. DERMAN, MARTIN F. SCHWELLNUS, DALE E. RAE, YUMNA ALBERTUS-KAJEE AND MICHAEL I. LAMBERT

6 Sports Cardiology, 232
CHRISTOS KASAPIS AND PAUL D. THOMPSON

7 Sports Pulmonology, 268
JOSEPH CUMMISKEY, KAI-HÅKON CARLSEN, KEUN-YOUL KIM, CONLETH FEIGHERY, ANDREW GREEN, FABIO PIGOZZI, WALTER CANONICA, VITO BRUSASCO, STEFANO DEL GIAOCO, SERGIO BONINI AND MATTEO BONINI

8 Endocrinology, 302
JEFFREY M. ANDERSON, THOMAS H. TROJAN AND WILLIAM J. KRAEMER

9 Dermatology, 326
BRIAN B. ADAMS

10 Exercise and Infections, 344
MARTIN P. SCHWELLNUS, AUSTIN JEANS, SELLO MOTAUNG AND JEROEN SWART
vi CONTENTS

11 Gastrointestinal System and Exercise: A Clinical Approach to Gastrointestinal Problems Encountered in Athletes, 365
   MARTIN P. SCHWELLNUS AND JOHN WRIGHT

12 Exercise and the Kidney, 375
   BRIAN RAYNER AND MARTIN P. SCHWELLNUS

13 Obstetrics and Gynecology, 390
   RAUL ARTAL AND SUSAN HOFFSTETTER

14 Neurologic Problems in Sport, 412
   PAUL MCCRARY

15 Medical Care of the Disabled Athlete, 429
   DOUGLAS B. MCKEAG AND CHRIS KLENCK

16 Environmental Sports Medicine, 444
   TIMOTHY D. NOAKES, TAMARA HEW-BUTLER AND ROSS TUCKER

17 Drugs in Sport, 482
   DON H. CATLIN, GARY GREEN AND CAROLINE K. HATTON

18 Emergency Sports Medicine, 504
   LUCY-MAY HOLTZHAUSEN AND CHRIS HANNA

19 Genetics and Sports Participation, 548
   KYRIACOS I. ELEFHERIOU AND HUGH E. MONTGOMERY

   LOUISE M. BURKE

Index, 601
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Foreword

This Volume represents the XIVth volume of The Encyclopaedia of Sports Medicine series, scientific publications by the IOC Medical Commission which began in 1988 with Volume I, The Olympic Book of Sports Medicine. To produce each volume, the most respected clinicians and scientific investigators have collaborated to produce reference texts that are both comprehensive for the topic and representative of the leading edge of knowledge.

The positive impact of the Encyclopaedia on a central theme, the health and welfare of all persons participating in sport, has exceeded all expectations.

Volume XIV, The Olympic Textbook of Medicine in Sport, addresses the clinical issues that were included in the original Volume I and synthesizes the new research information that has been published during the intervening 20 years. I wish to congratulate Professor Martin Schwellnus and all of the Contributing Authors on the excellent quality of this publication.

Dr Jacques Rogge
President of the International Olympic Committee
Preface

Sports and Exercise Medicine can be defined as that scope of medical practice which focuses on (i) the prevention, diagnosis, treatment and rehabilitation of injuries that occur during physical activity, (ii) the prevention, diagnosis, and management of medical conditions that occur during or after physical activity, and (iii) the promotion and implementation of regular physical activity in the prevention, treatment and rehabilitation of chronic diseases of lifestyle. Over the past two to three decades, there has been an exponential increase in the number of published research articles, books and other publications that cover these areas of medical practice. In general, most publications (in particular textbooks) cover the first (injury prevention and treatment) and the third (chronic disease prevention and rehabilitation) areas of Sports and Exercise Medicine very well. However, the area in Sports and Exercise Medicine that has not received the same attention in the published literature is the prevention, diagnosis, and management of medical conditions that occur during or after physical activity. It is for that reason, that this new volume of *The Encyclopaedia of Sports Medicine* series has been compiled, specifically to provide sports medicine practitioners with a systematic approach to this very important aspect of sports medicine practice.

It is well recognized that the team physician, including the members of the medical team attending to Olympic athletes, commonly encounter medical problems that are non-injury related. It has been reported that about 50% of the 1804 athletes seen at the multipurpose medical facility at the 1996 Olympic Games were seen for treatment of non-injury related illnesses. A similar pattern has been observed in subsequent Olympic Games, and this is also a common observation by team physicians who travel with athletes in other sporting disciplines.

In compiling this volume, it was therefore decided to follow a systemic approach that will provide the sports medicine practitioner with a clinical approach to the prevention, diagnosis and treatment of common and less common medical problems encountered in athletes. This volume contains 20 chapters. The first three introductory chapters deal with the basic approach to training, monitoring training and the clinical implications of excessive training. The remaining 17 chapters systemically deal with all the major systems in the body, and focus on medical conditions that athletes may suffer from in each system. Special mention has to be made of three novel chapters that focus on medical conditions in athletes with disabilities, genetics and exercise and emergency sports medicine. Each chapter editor was selected on the basis of their expertise, and chapter editors were also encouraged to solicit contributing authors for specialized sections within chapters. This approach has led to a volume that has an impressive list of authors – all experts in their field.

It has been a privilege for me to work with these experts in compiling this volume, and I trust that you as the reader will find the volume inspiring, comprehensive and a truly novel resource that will be consulted regularly in your practice. I also trust that the use of this volume by sports practitioners will also ultimately improve the medical service to our athletes.
Acknowledgements

I would like to sincerely thank all the chapter editors and contributing authors for their hard work, dedication, and willingness to share their expertise. In particular, I would like to thank all of the contributors for giving up time amidst their very busy schedules. A special thanks has to go to Professor Howard Knuttgen, Coordinator of Scientific Publications for the IOC Medical Commission, for initiating this project, and for his constant support and encouragement. Also many thanks to the editorial and support staff at Blackwell for their support. Finally, thanks to the IOC Medical Commission and the International Sports Medicine Federation (FIMS) for allowing me to edit this volume in the Encyclopaedia series.

Martin P. Schwellnus, MBBCh, MSc, MD
Chapter 1

General Principles of Training

MICHAEL I. LAMBERT, WAYNE VILJOEN, ANDREW BOSCH, ALAN J. PEARCE AND MARK SAYERS

Exercise training can be defined as a systematic process of preparing for a certain physical goal. This goal used to be synonymous with peak physical performance; however, exercise training is also used to achieve targets for health-related fitness. As society evolves and becomes more sedentary (Dollman et al. 2005) there is greater emphasis on habitual physical activity with the aim of reducing obesity, adult onset diabetes, hypertension and the risk of heart disease. Indeed, there are specific guidelines which have been written for prescribing exercise for these conditions (American College of Sports Medicine 1998).

An understanding shared by coaches and athletes alike, all over the world, is the general concept that physical performance improves with training (Foster et al. 1996). The specific guidelines on how to achieve peak performance are not so clear, because of the diverse capabilities, goals and types of sport. For example, a sedentary person may have a goal of training to develop sufficient fitness for running 5 km without stopping. This can be compared to the goal of a professional athlete who trains according to a program with the aim of reducing his 5-km time by 3 s. However, irrespective of the goal, there are basic principles of training which can be applied to plan training programs.

Training for peak sporting performance includes training for physical development (general and sport-specific factors), and technical and tactical training (Bompa 1999). Athletes also have to train psychologic aspects and in team sports athletes have to train for the development of team compatibility to ensure harmony within the team structure. To complete the requirements for achieving peak performance, athletes need to be healthy and free of injuries and have a theoretical knowledge of their training in preparation for their sport so that they can take some responsibility for their progress (Bompa 1999).

Long-term planning for the career of an elite athlete covers 10–15 years (Smith 2003). However, the age at which competitors reach their peak varies according to the sport. For example, in sports such as gymnastics, figure skating, and swimming competitors reach their peak in their late teens or early twenties, in contrast to other sports such as soccer, rugby, and distance running where competitors reach their peak success in their late twenties or early thirties (Bompa 1999). In sports such as golf and lawn bowls, in which the technical attributes are the most important factors determining success, the age of elite performers may be 40 or 50 years. Generally, the starting age of athletes in the more technical sports, which require the development of fine motor coordination skills, is younger than athletes competing in sports that are less technical but depend more on physical ability.

This chapter discusses the evolution of training principles with a contemporary view of the factors that need to be considered in devising a training program. Specifically, it discusses the principles of training programs that are designed to improve peak performance coinciding with competition.
This is followed by sections on specific training principles for strength, endurance, and skill acquisition.

**History**

Exercise training to improve performance can be traced back to early civilizations (Kontor 1988). There is evidence for both strength training and strength contests as early as 2040 BC with illustrations of weightlifting and strength movements on the tomb of the Egyptian Prince Baghti (Stone et al. 2006). Other forms of training are described in folklore. For example, there is the story of the Milo the Greek wrestler who won six titles at the Olympic Games, getting his first title in 540 BC. In preparation for his competition Milo supported a calf above his head daily. As the calf grew, Milo became stronger and was the credited with being the first person to practice the principle of overload (Kontor 1988).

This principle was only studied systematically nearly 2500 years later (Hellenbrandt & Houtz 1956). Planning a training program for improving performance was documented by Flavius Philostratus (AD 170–245), a coach of Greek Olympians. He mentioned that a coach should “be a psychiatrist with considerable knowledge in anatomy and heritage” (Bompa 1999).

In Britain towards the end of the 18th century methods of training were discussed by trainers of athletes from different sports involving humans (runners, boxers) and animals (racehorses) (Radford 2000). The description of these training methods became more formal after Sir John Sinclair completed a national survey of coaching methods and published his findings in 1806. These guidelines for training were based on anecdotal evidence and personal experiences of coaches and were devoid of any scientific testing or scrutiny. During this era, success in high performance sport could be attributed mainly to two factors: (i) the athlete had a predisposition to the sport; (ii) a coach with a disciplined approach to training supervised the athlete (Lambert 2006).

The first scientific investigation into sports training methods occurred in 1950 (Tipton 1997) and since then there has been an acceleration in the discussion and scientific evaluation of athletic training programs (Booth et al. 2000).

The “scientific approach” to training coincided with the application of the principles of sports physiology to training (Tipton 1997). This initiated a systematic application into training programs of interval training (Laursen & Jenkins 2002) and other types of training such as acceleration sprints, circuit training, continuous fast running, continuous slow running, fartlek training, jogging, and repetition running.

During the 1960s and 1970s the development of sports science coincided with the transition of amateur into professional sports (Booth et al. 2000). This also prompted creative thinking about improving performance through strategies other than training. Not all the methods were accepted. Indeed, the use of drugs to improve performance was banned by the International Olympic Committee (IOC) and implemented at the Olympic Games in Mexico City in 1968 (Papagelopoulos et al. 2004). Nearly 40 years later this problem is still rife in competitive sport, with athletes and their medical support staff becoming more elusive in their use of drugs. This is countered by the authorities who have to invest large amounts of money to use more sophisticated methods to detect athletes who have used any substance that appears on the IOC banned list.

Equipment has also improved over the years and contributed significantly to an improvement in performance in sports such as golf, soccer, kayaking, cycling, and javelin. This has resulted in legislation standardizing the equipment to prevent competitors from having an unfair advantage over their rivals with less sophisticated equipment. A specific example of equipment influencing performance is pole vaulting where at the 1896 Olympics a bamboo pole was used and the height achieved was 3.2 m. In modern times, with the use of poles made out of carbon-fiber composite material, the current world record is nearly double that at 6.14 m (2008).

Despite the refinement in the preparation for elite performances, the improvement in world records in the last 20 years has been moderate. For example, the World Record in the marathon has improved by 2 min 17 s (1.8%), the 10,000 m and 5000 m track race times by 56 s (3.4%) and 22 s (3.0%), respectively, and the shot put distance has increased by 50 cm (2.2%) during this time.
In summary, the factors associated with improvement in the performance of contemporary athletes compared with the top athletes several decades ago are:

- Improvements in coaching;
- Advances in nutrition;
- Perfection of athletic facilities;
- Refinement of equipment; and
- Contributions from sports medicine (Tipton 1997).

**Biologic process of training**

Exercise training can be explained according to the principles of biologic adaptation. In accordance with this explanation, each training session imposes a physiologic stress (Brooks et al. 2005). As with all forms of physiologic stress, there is a homeostatic reaction. This results in transient physiologic and metabolic changes (Coyle 2000) which return to their pre-exercise resting levels during the recovery period when the exercise session is over. Examples of these transient changes are as follow (Brooks et al. 2005):

- Altered blood flow to the active muscles;
- Increased heart rate;
- Increased breathing rate;
- Increased oxygen consumption;
- Increased rate of sweating;
- Increased body temperature;
- Secretion of stress hormones such as adrenocorticotropic hormone (ACTH), cortisol and catecholamines;
- Increased glycolytic flux; and
- Altered recruitment of muscles.

If these acute bouts of exercise are repeated over time they induce chronic adaptations that are also known as training adaptations (Coyle 2000). Most of these changes involve remodeling of protein tissue as a consequence of changes between protein synthesis and degradation (Mader 1988). These changes are semi-permanent and do not disappear after the bout of exercise or training session. However, they do regress if regular exposure to the stress of training ceases, as occurs during periods of detraining (Mujika et al. 2004). Training adaptations result in altered metabolism (Coyle 2000), changes in neuromuscular recruitment patterns during exercise, and remodeling of tissue (Hakkinen et al. 2003). The specific type of changes that occur after training depend on the type of stimulus, defined by the mode of exercise, intensity, and volume of training (Brooks et al. 2005; Coyle 2000). For example, the outcome of a resistance training program can increase either muscular endurance, hypertrophy, strength, or power. This depends on the manipulation of the training variables: (i) muscle action; (ii) loading and volume; (iii) selection of exercises and the order in which they are performed; (iv) rest periods; (v) repetition velocity; and (vi) frequency (Bird et al. 2005). The choice of the application of the training load (free weight vs. machine weights) can also influence the type of adaptation (Stone et al. 2000a).

The overt symptoms of training adaptations are shown by well-defined muscles, low body fat, and skillful movements. The covert symptoms of training are increased mitochondria in skeletal muscles (Irricher et al. 2003), increased capillarization (Henriksson 1992), cardiac hypertrophy (Urhausen & Kindermann 1992), and increased density of bones (Chilibeck et al. 1995). The first signs of increased capillarization occur about 4 weeks after starting a training program (Jensen et al. 2004), while it takes at least 4 weeks for the mitochondrial mass in the skeletal muscle to increase (Lambert & Noakes 1989). A few days after starting an endurance training program there is an increase in plasma volume (Green et al. 1990), while an altered muscle recruitment is the earliest adaptation that occurs after resistance training (Carroll et al. 2001; Gabriel et al. 2006). This is followed by muscle hypertrophy which occurs after about 8 weeks, depending on the training status of the athlete.

Training adaptations can be classified either as those changes that increase performance (through either an increased muscle power, increased ability to resist fatigue, or increased motor coordination) or those changes that reduce the risk of injury. There is generally a positive relationship between training load and the physiologic adaptations resulting in improvements in performance. However, if a critical training load is exceeded there will be diminishing returns. For competitors at the elite level there is a fine line between insufficient training or too much training (Kuipers & Keizer 1988; Lehmann et al. 1993; Meeusen et al. 2006; Morton 1997).