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# Clinical Exercise Testing

Edited by  
S.A. Ward and P. Palange



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# **Clinical Exercise Testing**

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Editor in Chief  
K. Larsson

This book is one in a series of European Respiratory Monographs. Each individual issue provides a comprehensive overview of one specific clinical area of respiratory health, communicating information about the most advanced techniques and systems needed to investigate it. It provides factual and useful scientific detail, drawing on specific case studies and looking into the diagnosis and management of individual patients. Previously published titles in this series are listed at the back of this book with details of how they can be purchased.

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# The Guest Editors



S.A. Ward



P. Palange

## The Guest Editors

Susan Ward is Professor of Sport and Exercise Science within the Institute of Membrane and Systems Biology at the University of Leeds, Leeds, UK. Susan gained her DPhil in Physiology from Oxford University in 1974. Following two years as a Lecturer in the Dept of Physiology at Liverpool University she moved to the University of California (Los Angeles, CA, USA), where she became Prof. of Anesthesiology and Physiology in 1988. She returned to the UK in 1993, first to the Dept of Physiology at the University of London's St George's Hospital Medical School, then to South Bank University as Chair of Sports Science. In 1998, she moved to the University of Glasgow as Director of the Centre for Exercise Science and Medicine.

In 2003, she was appointed as Chair of Sport and Exercise Science and Head of the School of Sport and Exercise Sciences at the University of Leeds. Her research interests include the control of ventilation, pulmonary gas exchange and muscle energetics during exercise in health and disease. In total she has over 120 publications on these topics. She is a Fellow of the American College of Sports Medicine and of the European College of Sports Science. Susan is a Principal Editor of the *European Journal of Applied Physiology*. She currently serves as Chair of the Pulmonary Circulation, Gas Exchange and Exercise Group of the European Respiratory Society (ERS).

Paolo Palange studied Medicine at the University of Rome and received his MD in 1981. In 1986, he obtained a specialty degree in Internal Medicine, followed two years later by a degree in Pulmonology. He began his career at the University of Rome as an Assistant Professor. In 2005, he was appointed as Associate Professor of Internal Medicine. Paolo is also the Director of the Pulmonary Function unit at the same institute. His main clinical interests include asthma, lung function testing and sleep disorders. Throughout his career Paolo has carried out research in many key areas including exercise pulmonology, pulmonary gas exchange and the systemic effects of COPD.

As well as his clinical work Paolo has also been actively involved in the ERS in a variety of different roles. From 1993–2000 he represented the Scientific Group, Gas Exchange and Exercise, as both Group Secretary and Group Head. Since then he has chaired numerous ERS Research Seminars and Task Forces. His most recent, and current position, is ERS School Director of the Postgraduate Courses.

# Preface

The majority of diseases and pathological conditions reduce physical capacity, which may have an influence on every day life. This is particularly the case for individuals suffering from respiratory diseases that frequently lead to symptoms during physical activity. The symptoms that usually reduce physical performance are leg fatigue, pain and dyspnoea; the latter is the most common in respiratory diseases. Dyspnoea is a subjective feeling of not getting enough air and constitutes a disabling symptom, which may severely circumscribe physical activity in patients with pulmonary diseases. As there is no specific available treatment for dyspnoea, it has to be alleviated by treatment of the underlying disease. As dyspnoea is connected with physical activities, it is crucial to understand the mechanisms and the methodology for assessing symptoms associated with exercise; when diagnosing and monitoring patients with respiratory diseases we often have to rely on surrogate markers. The exercise test constitutes a possibility to directly assess the physical capacity, thus providing a good insight into how the disease influences physical performance. Therefore, the exercise test is a valuable tool in diagnosing and staging disease severity, and as a guide for pharmacological and nonpharmacological treatment and action plans. In order to obtain a comprehensive view of the nature of reduced physical capacity the exercise test has to be adjusted to the individual issue with questions relating to the patient.

Exercise tests have been used for a long time as diagnostic tools for cardiac diseases. During recent years they have become more widely recognised as valuable instruments in the diagnosis and monitoring of pulmonary disorders. In the present issue of the *European Respiratory Monograph*, cardiopulmonary exercise testing for cardiac and pulmonary diseases has been presented. Techniques and equipment as well as reference values have been thoroughly described. The specific questions that arise in children have been addressed and exercise testing as a tool for the assessment of prognosis and treatment effects has been exhaustively presented. It is now 10 years since the last *European Respiratory Monograph* on exercise testing was published. This area has developed and there is a lot of new information, in particular regarding physical activity and exercise physiology associated with chronic obstructive pulmonary disease. Therefore, it is timely to update the knowledge in this field and to publish an issue of the *European Respiratory Monograph* that will be helpful to clinicians, physiologists, nurses, physiotherapists and other professionals interested in exercise physiology and testing.

**K. Larsson**  
Editor in Chief



## INTRODUCTION

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Since the publication of the first *European Respiratory Monograph* on "Clinical Exercise Testing" in 1997, the scope of, and clinical insights attendant to, exercise testing has matured to a point where it has become a relatively common element in the elucidation of causes and management of diseases for which exercise intolerance is a cardinal feature. This stems from the recognition that an exercise test which is appropriately designed and executed, with its results perceptively interpreted, allows not only the degree of exercise intolerance to be quantified, but also provides the potential for its mechanism(s) to be elucidated in the context of a patient's integrative physiological system function. This is based on the tenet that the critical source of system failure can be induced while the system(s) (e.g. muscle-energetic, cardiovascular, pulmonary) is under an appropriate exercise stress in a controlled environment. The symptom-limited incremental (or ramp) exercise test remains the "gold standard" in this regard, as it provides a smooth gradational and quantifiable metabolic stress over the patient's entire range of tolerance. In addition, a substantial body of evidence has accrued to demonstrate that the incremental exercise test is central to the optimisation of work-rate intensity for exercise-based rehabilitation and interventional assessment, and can also impact on the prognosis related to outcome from major surgery, post-operative triaging and even life expectancy.

The present, new edition, of the *European Respiratory Monograph* on "Clinical Exercise Testing" is designed to complement and extend the scope of its predecessor. The first two chapters provide a physiological frame of reference for subsequent considerations of the pathophysiology and management of clinical exercise intolerance. The contributions of the muscle-energetic, cardiovascular, pulmonary gas-exchange and ventilatory system responses to the stress of muscular exercise in health are considered, together with their putative limiting factors. This is followed by an assessment of how altered responses may be discriminated and interpreted in relation to key indices of these system functions, as typically discerned from the results of incremental and constant-load exercise tests. In the following two chapters these concepts are extended to considerations of the causes of exercise intolerance in diseases such as chronic obstructive pulmonary disease, interstitial lung disease, pulmonary vascular diseases and chronic heart failure.

Chapters 5, 6 and 7 focus on the technical aspects of contemporary testing procedures. These range from analysis of equipment specifications, breath-by-breath algorithms, calibration techniques and quality control procedures to laboratory- and field-based exercise testing paradigms. The latter aspect, in particular, represents a new addition to the Monograph, reflecting the growing demand for a simpler "alternative"

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to the cardiopulmonary exercise test, and one which has already been shown to provide useful value in the context of interventional assessment in chronic lung disease.

In the following four chapters, the emphasis moves on to the testing of two particular populations: patients with lung disease (both children and adult) and heart disease. Central to the interpretation of exercise test results is the availability of robust sets of normative or reference values. Considerations of exercise testing in prognostic evaluation and in the assessment of responses to interventions (*e.g.* exercise training, supplemental oxygen and drug therapies) provide a further addition to the previous Monograph. In the final chapter, the indications for exercise testing in clinical practice are discussed, along with proposals for new directions in the development and application of clinical exercise testing.