Exercise testing and interpretation

A practical approach

In *Exercise Testing and Interpretation: A Practical Approach*, Drs Christopher Cooper and Thomas Storer offer a practical and systematic approach to the acquisition, interpretation, and reporting of physiologic responses to exercise.

Pulmonologists, cardiologists, and sports physicians, as well as respiratory therapists and other allied health professionals, will find this book an indispensable resource when learning to select proper instruments, identify the most appropriate test protocols, and integrate and interpret physiologic response variables. The final chapter presents clinical cases to illuminate useful strategies for exercise testing and interpretation. Useful appendices offer answers to frequently asked questions, laboratory forms, algorithms, and calculations, and a glossary of terms, symbols, and definitions. *Exercise Testing and Interpretation: A Practical Approach* offers clearly defined responses (both normal and abnormal) to over 40 performance variables including aerobic, cardiovascular, ventilatory, and gas exchange variables.

Practical, portable, and easy-to-read, this essential guidebook can be used as a complement to more detailed books on the topic, or stand on its own.

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Dedicated to Nancy and Paula

''Those who do not make time for exercise will eventually have to make time for illness''

The Earl of Derby (1863)

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Preface

Exercise is fundamental to human existence. For most men and women exercise is essential for quality of life and for many it is the essence of their livelihood. Some have a competitive instinct for athletic performance in the pursuit of individual human achievement. We now understand that the maintenance of physical fitness throughout life is crucial if we are to remain healthy and live to an advanced age. In these contexts, the assessment of exercise ability is of considerable importance to humanity. Exercise testing becomes the means of assessing ability to perform specific tasks, quantification of athletic performance, diagnosis of disease, assessment of disability, and evaluation of responses to physical training, therapeutic intervention, and rehabilitation.

Recent years have indeed witnessed widespread applications of exercise testing that range from clinical uses in assessing debilitated patients to sports medicine venues and the testing of élite athletes. Some exercise tests are appropriately performed with a minimum of equipment, such as a watch and a measured course. Others involve more sophisticated instrumentation enabling more detailed assessments. Advances in technology have rendered all exercise tests more accessible and more affordable, although not necessarily easier to perform with accuracy and reliability. Wireless heart rate monitors give instantaneous and reliable heart rates in the field or in the laboratory. Bi-directional, light-weight, mass flow sensors have obviated the need for cumbersome valves and tubing and, together with miniaturized and fast-responding gas analyzers, enable the calculation of oxygen uptake with every breath. Computer technology has

revolutionized the real-time acquisition and analysis of data, although not necessarily made exercise tests any easier to interpret.

We have both practiced and taught in the field of exercise testing and interpretation for many years. We saw the need for a practical text that succinctly explains the physiology of exercise and also gives detailed advice regarding the conduct and interpretation of exercise tests in a variety of settings. We have included clinical and sports medicine applications because we are convinced that these disciplines will merge in the future. We have addressed technical considerations, pitfalls, and solutions. We have placed emphasis on creative figures and diagrams to offer systematic explanations and schemata for interpretation. We have also attempted to address the confusion that surrounds terminology in this diverse field. We have done so through a systematic, logical, and critical examination of the concepts and applications of the field. We hope our approach is enlightening and not a mere addition to the plethora of terms and symbols already in use.

Exercise testing, which we abbreviate to XT, can be conducted for several purposes, in a variety of settings. *Performance* exercise tests (PXT) can be performed in the *field* or *laboratory* using a selection of protocols, depending upon the purpose of the test. Typicaly, PXT are conducted to establish exercise-training guidelines and to monitor progress. *Clinical* exercise tests (CXT) have a somewhat different emphasis and are almost exclusively conducted in a laboratory setting. CXT can be *diagnostic*, seeking an explanation for exercise impairment; for *risk assessment*, such as from coronary artery disease or surgery; or alternatively for *monitoring*, for example to quantify the response to therapeutic or surgical interventions or to document progress in rehabilitation. Exercise capacity can be measured by different protocols ranging from the time required to complete a measured course to the acquisition of a wide range of cardiovascular, ventilatory, and gas exchange variables. *Functional* exercise tests focus on ability to perform a specific task whereas *integrative* exercise tests compile an array of variables with which to study the underlying physiology of the exercise response.

Several features of this book are unique. The core of the book describes instrumentation and protocols for exercise testing followed by response variables and their interpretation. The book is laid out so that the reader can easily locate a piece of equipment or response variable for ready reference. Chapter 2 (Instrumentation) describes apparatus for exercise testing explaining, succinctly, the principles of operation and essential facts about calibration and maintenance of the equipment. Chapter 3 (Testing methods) describes protocols for exercise testing with many important details, gleaned from years of experience, that facilitate a successful test. Chapter 4 (Response variables) expands on the many physiological variables that can be derived from exercise testing, ranging from simple timed distances to the complex integrated cardiovascular and gas exchange variables which underlie the exercise response. Each variable has its own section including a definition, derivation, and units of measurement, along with examples of the normal and abnormal responses. Chapter 5 (Data integration and interpretation) presents a novel and systematic approach to help the reader develop a confident and meaningful interpretation of the data. There is an emphasis here on integrative exercise testing because interpretation of this type of XT has often presented more problems to the exercise practitioner. Chapter 6 illustrates the principles expounded in Chapters 2 through 5 with a selection of real cases. Finally, the appendices are designed to be a valuable resource for the exercise practitioner. They include a glossary of proper terms and symbols as adopted by exercise physiologists, simplified algorithms to help explain the derivation of secondary variables, predicted normal values with appropriate critique, examples of worksheets that facilitate testing, and a section on frequently asked questions.

Finally, a few words about the units of measurement incorporated in this book. Our goal has been to write a book that will be of practical value to persons throughout the world who are involved in

exercise testing and interpretation. As such we have had to deal with certain inconsistencies in currently accepted units of measurement. Some countries, including the USA, continue to use imperial rather than metric units for certain measurements. The *Système International d'Unités* attempts to bring everyone into concordance with a metric system. However, some traditional units do not lend themselves comfortably to this conversion. We have used SI units wherever possible but referred to traditional units as well when conversion was not straightforward. Readers will undoubtedly find some inconsistencies and discrepancies but hopefully these can always be resolved by reference to Table B1 in Appendix B which explains any necessary conversions.

This book is intended to be a practical text which exercise practitioners would want readily available in their clinical or research laboratories, rehabilitation facilities, and sports clubs. The book may prove useful for chest physicians, cardiologists, exercise physiologists, occupational health physicians, sports physicians, sports scientists, laboratory technicians, physical or respiratory therapists, medical students, and postgraduate students in the exercise sciences. The material for the book has evolved over many years of teaching exercise physiology, exercise testing, and interpretation. Parts of the book reflect a syllabus that we have developed and refined over the past eight years for an annual symposium that has taken place at UCLA as well as several national and international venues. Reflecting our own careers and experiences, we have tried to approach the topic simultaneously from the perspectives of exercise science and clinical medicine. By doing so we have attempted to develop a comprehensive and balanced view of a complex subject which we hope will appeal to, and draw together, a broad range of disciplines with a common purpose – that of understanding the human exercise response.

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This book has evolved from what we have learnt from our mentors, students, and patients. However, its production owes much to the support of others. We wish to thank the staff at Cambridge University Press, particularly Jocelyn Foster who was involved at the conception of the project and Liz Graham who undertook the formidable task of copyediting. We are especially indebted to Judy Valesquez for her meticulous preparation of the figures. Finally, we must acknowledge our families for accepting the many hours we were not with them.

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