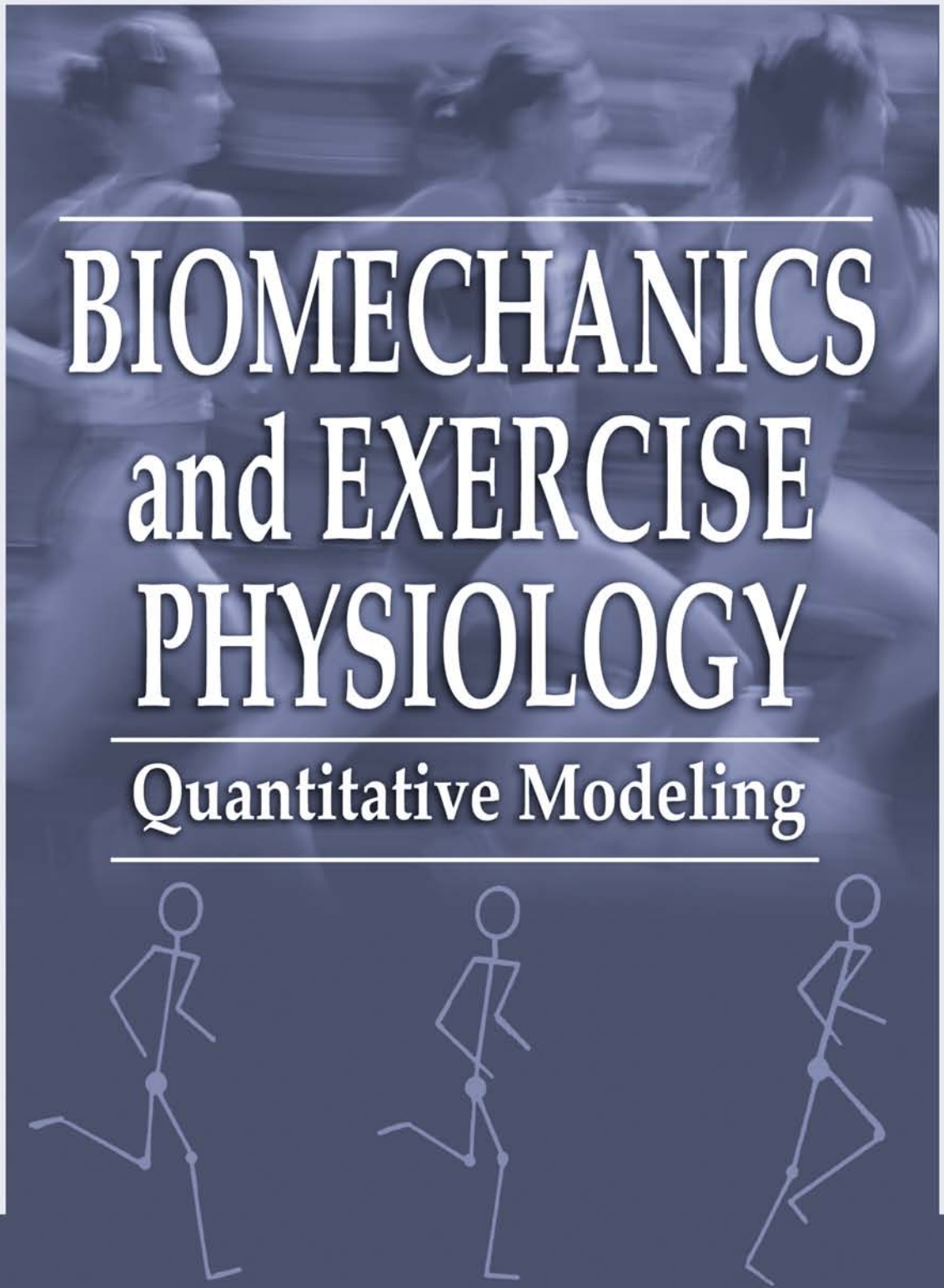

BIOMECHANICS and EXERCISE PHYSIOLOGY

Quantitative Modeling

ARTHUR T. JOHNSON

CRC Taylor & Francis
Taylor & Francis Group

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This book is dedicated to Miss Mary R. Humpton,

high school teacher and advisor at Newfield Central School,

who was much more than a teacher to the class of 1959.

Preface to the Second Edition

The year was 2003 and the place was Las Vegas. The first edition had been out of print for several years. Taylor & Francis (then Marcel Dekker) representative Susan Lee and I sat in a couple of chairs in front of a bank of slot machines to talk about my interest in updating this book. By that time, I was aware of the shortcomings of the first edition: there were too many errors, symbol notations were not always consistent, worked examples were needed, homework problems had to be added, and new research results were currently available. So, as we talked in the presence of those slots, it seemed that a second edition was needed.

When I wrote the first edition of this book, I wanted readers to know that physiological responses, especially to exercise, could yield to engineering analysis just as any other engineering problem. I needed to compile the vast amounts of information available in diffused and sundry sources into one place easily accessible to bioengineers. I had also learned from my second book, *Biological Process Engineering*, that there is often a great leap of understanding that separates the presentation of an equation from its numerical application to a real problem. So, convinced more than ever that engineers and physiologists who wish to predict human responses to the challenges of life processes can have the means to do so, I agreed to update this book. It was not an easy decision because at the time I was writing *Biology for Engineers*, but this book had been unique and now I could make it more effective.

Neither of us inserted money into the nearby slot machines that day, so we did not find out if we would have won or lost. Nonetheless, I hope you will agree that during that Las Vegas conversation we all hit the jackpot.

Preface to the First Edition

> We frequently hear the complaint that as the boundaries of science are widened its cultivators become less of philosophers and more of specialists, each confining himself with increasing exclusiveness to the area with which he is familiar.
>
> —James Clerk Maxwell

Every author has much to explain, and the preface serves as a confessional vehicle. It also provides an opportunity for an author to define the philosophy behind the writing; moreover, it tells the reader what to expect.

Therefore, I begin by confessing why I wrote this book. Dr. Ralph Goldman is the cause: he showed me that it is possible to quantitatively predict exercise thermal response. Once I saw that, I was hooked—what became most interesting to me was to see what could be predicted. If all exercise responses could be described in equation form, we could start using these equations in exciting ways—designing optimized equipment, producing more convenient respiratory protective masks and similar products, improving training procedures, and, of course, circumventing the university's Human Subjects Committee by resorting to computer modeling. Teaching of physiology would become more precise because models contain precise, though not necessarily accurate, information. Gone would be terms like ''relatively large,'' ''dominant,'' ''acute,'' and ''chronic''; in their places would be glorious equations with numbers and precise definitions. Therefore, I started planning this book long ago: gathering information, classifying it, and filing it away for later reference.

But why exercise? Exercise is a natural stressful condition for which the body has been built. The physiology of rest is interesting enough, but look at all the changes, compensations, and feedback loops that are manifested during exercise! They are extremely fascinating.

I confess next that this book does not contain all the information about exercise that various experts know should really be included. However, I hope that one strength of the book is its scope. Although large volumes have appeared on respiratory models, cardiovascular models, and thermal models, not one addresses all three areas. So start here with an overview, then find more details in other tomes. I have tried to include all pertinent concepts, although not all pertinent embellishment. The scope of this book is so broad that I probably would not yet have attempted it, except that Tom Milhorn, author of *The Application of Control Theory to Physiological Systems*, told me how he began writing his inspiring book ''before he knew any better'' when he was a graduate student.

I confess, too, that, although I tried to include as much physiology as necessary (and I am reasonably familiar with physiology), I wrote this book as an engineer. I am extremely proud to be an engineer; engineering has taught me to organize thoughts, concepts, and information. I hope there is a reasonable amount of good in this book for those who are not engineers, as well.

The models I chose to include in this book are not always the most modern. Indeed, I confess to having purposely passed over a number of exacting recent models to include some earlier ones. My reason for this was pedantic: some of the older models, although less detailed, give better overviews of the systems they model. Therein lies the connection with the quotation from Maxwell at the beginning of this preface.

My biggest confession concerns units. Oh, what headaches! Every sub-, sub-, subdivision of every specialty uses different units. As an example, consider pressure drop by engineers in inches of water, by industrial hygienists in centimeters of water, by physicians in millimeters of mercury, and by some others in atmospheres; or consider rate of work by power engineers in horsepower, by electrical engineers in watts, by exercise physiologists in kilopond-meters per minute, and by industrial hygienists in centimeters of water times liters per second. I talk to all of these, and it means constantly juggling conversion factors in my head. When I began writing this book I started using the prevailing units for each object of scrutiny. It soon became apparent that in this method lay madness. Thus, you will find straight metric units here, and not even International Systems units, because a joule is called a newton meter, and a watt, or joule per second, is called a newton meter per second. To accommodate those readers who talk to people in other specialties, I have included some units in parentheses. Perhaps after seeing the standard set of units used here, you will appreciate why other units are still used.

I also had a problem with the title of the book: it could have included the words ''biomechanics,'' ''ergonomics,'' ''exercise physiology,'' ''labor,'' or ''stress''—all recognizable to a portion of the technical field I wish to address. However, what do you do when you are dealing with a multidisciplinary subject? You call it what you will, and hope for the best.

Now that I have confessed, I feel better. I hope it was not too painful for you. Maybe the next edition of this book will have a section on your work and a shorter preface as a result.

Arthur T. Johnson
College Park, MD
January 1991

Acknowledgments for the Second Edition

I wish to thank Ms. Janet Woodruff for all her hard work scanning the first edition, correcting errors, and typing on and on, it seems, until it was done. I also thank Ms. Erika Lopresti for her work on the new drawings, and Ms. Katie Helene for her assistance with permissions. Dr. Karen Coyne identified and compiled many of the errors in the first edition, and thanks to the many sharp-eyed students who found errors and told me about them.

Acknowledgments for the First Edition

> Jupiter has loaded us with a couple of wallets: the one, filled with our own vices, he has place at our back; the other, heavy with those of others, he has hung before.
>
> —Phaedrus

I am deeply indebted to many for the final production of this book. Thanks to Mrs. Thelma deCheubel for typing the early drafts, thanks to Mr. Lovant Hicks for the excellent drawings, and a special thanks to Cathy, who typed the final draft, counting down each equation in turn and cringing at my split infinitives.

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