The Biophysical Foundations of Human Movement

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HUMAN
KINETICS

Library of Congress Cataloging-in-Publication Data

The biophysical foundations of human movement / Bruce Abernethy . . . [et al.].
p. cm.
Includes bibliographical references and index.
ISBN 0-88011-732-X
1. Human mechanics. 2. Biophysics. I. Abernethy, Bruce, 1958-

QP303.B586 1997 96-50009
612.7'6--dc21 CIP

ISBN: 0-88011-732-X

First published in Australia in 1996 by Macmillan Education Australia of 107 Moray Street, South Melbourne, Victoria 3205. (ISBN 0-7329-3048-0, paper; ISBN 0-7329-3047-2, cloth)

This international version published in 1997 by Human Kinetics Publishers, Inc.

Managing Editor: Lynn M. Hooper; **Text and Cover Designer:** Jan Schmoeger; **Typesetting:** Typeset Gallery, Malaysia; **Indexer:** Kathleen Gray; **Printer:** United Graphics

Printed in the United States 10 9 8 7 6 5 4 3 2

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The Biophysical Foundations of Human Movement

Dedication

To all those scholars, past and present, who have contributed to the academic credibility of the study of human movement.

Preface

Knowledge about the biophysical foundations of human movement is important for a number of reasons. A thorough understanding of human movement is fundamental to professional practice in a range of fields such as exercise and sport science, physical education, medicine, physiotherapy, occupational therapy, nursing, and other rehabilitation and health-science professions. Furthermore, the study of human movement is also of value in itself as a means of examining key biological phenomena such as maturation, adaptation and the interactions between hereditary and environmental factors, which underpin growth and development.

Despite the central importance of movement, in an applied sense, to professional preparation in the health sciences and, in a basic sense, to the understanding of human biology, in teaching an introductory subject on the biophysical foundations of human movement we have been surprised at the absence of a suitable introductory textbook to cover this field. This text was written in an attempt to redress that shortfall.

The *Biophysical Foundations of Human Movement* was written with three main purposes in mind, namely to:

- provide an introduction to key concepts concerning the anatomical, mechanical, physiological, neural and psychological bases of human movement
- provide an overview of the multidimensional changes in movement and movement potential that occur throughout the lifespan with the processes of growth, development, maturation and ageing
- provide an overview of the multidimensional changes in movement and movement potential that occur as an adaptation to training, practice and other lifestyle factors.

Fulfilling the first purpose involves consideration of the biophysical dimensions of the field of study known variously as *human movement studies*, *human movement science*, *kinesiology*, or *sport and exercise science* and examination of the discipline–profession links in this field. Gaining an overview of the structure of the field is especially important for students taking courses in human movement studies as a means of providing an entrée to more detailed study within one or more of the subdisciplines of human movement studies and as a means of laying the foundations for integrative, multidisciplinary and crossdisciplinary studies.

Fulfilling the second and third purposes is important as a means of exposing readers to fundamental issues in biology itself and in positioning the study of movement as a major topic within human biology. We have deliberately selected *lifespan changes* and *adaptation* as key organising themes for this book because of their centrality to biology itself. Gaining

knowledge about the processes of growth, development, maturation and ageing aids understanding of the key changes in movement potential throughout the lifespan that, because of their inevitability, impact directly on all of us. Although the processes of maturation and ageing are inevitable, adaptation (through training, practice and lifestyle decisions) offers humans some degree of control of their own destiny and capabilities. It is our sincere hope that the clear message about the important role physical activity plays in the maintenance of health, which arises from consideration of adaptation within each of the biophysical subdisciplines of human movement, will be one that readers of the text will not only take to heart themselves in making personal lifestyle decisions but will also communicate to others.

The Biophysical Foundations of Human Movement has been intentionally structured into three major parts to broadly reflect its three main purposes. Part 1 provides a general introduction to human movement studies as a field of study. It does this by examining the disciplinary and professional structure of contemporary human movement studies (Chapter 1) and by providing a brief overview of the historical origins of the current academic field (Chapter 2).

Part 2, the largest part of the book, provides an introduction to basic concepts, to lifespan changes, and to adaptations arising in response to training, within each of the five major biophysical subdisciplines of human movement. These are the subdisciplines of functional anatomy, biomechanics, exercise physiology, motor control and sport and exercise psychology. These subdisciplines represent respectively the anatomical, mechanical, physiological, neural and psychological bases of human movement.

If a crude analogy was drawn between the human body and a motor vehicle (crude in the sense that the analogy would grossly underestimate the complexity, dynamics and adaptive potential of the human machine), then the various biophysical subdisciplines recognised within human movement studies have reasonable analogues in terms of the minimal 'clusters' of knowledge needed to explain and predict the functioning and 'behaviour' of the human 'motor vehicle'. The scientist attempting to understand the human body and its potential for movement is faced with synthesising some of the same general classes of knowledge that the automotive engineer needs in order to understand an inanimate motor vehicle and its potential for movement. To understand and optimise the performance of a motor vehicle the automotive engineer needs specific knowledge about the vehicle's material structure (its anatomical basis), its mechanical design characteristics (its mechanical basis), its motor's capacity and fuel consumption (its physiological basis), its electrical wiring and steering mechanisms (its neural basis), and the characteristics and capabilities of its driver (its psychological basis). In the case of the human 'vehicle' this information is provided by the subdisciplines of functional anatomy, biomechanics, exercise physiology, motor control and sport and exercise psychology and the interactions between them.

Within Part 2, each of the five biophysical subdisciplines of human movement studies is discussed in a separate section, with the structure of each of the sections being broadly the same. Each section begins with a brief introduction, which defines the subdiscipline and provides information on its historical development, the typical issues and problems it addresses, the level(s) of analysis it uses and relevant professional training and organisations. This introduction is then followed by a number of chapters that overview the basic concepts within each of the subdisciplines and is then followed by separate chapters devoted to consideration of lifespan changes and adaptation. The exercise physiology section also contains an additional chapter devoted to specific applications of fundamental principles of exercise physiology to health.

Part 3 of the book is devoted to multidisciplinary and crossdisciplinary approaches to human movement and provides some examples of contemporary issues in which the application and integration of knowledge from a number of the biophysical subdisciplines are fundamental to understanding. The material presented in this part of the text is designed to demonstrate

the importance of integration of information from different subdisciplines as being the essential strength and prospective direction for the academic discipline of human movement studies and for practice in those professions grounded in the knowledge base of human movement studies. A glossary of terms is supplied at the end of Part 3 to assist in the comprehension and revision of new terms introduced at various points in the text.

Throughout the book we have included a number of boxed sections, peripheral to the main body of the text, to highlight some key individuals and studies that have contributed to our understanding of human movement. Although the body of the text does not, as a general rule, focus on specific research studies or methods (a select list of further reading is given at the end of each section rather than detailed reference citations within each chapter), the boxed sections have been designed with the intent of providing the reader with some feel for the flavour of research methods in this field plus more detailed exposition of some of the pivotal studies that have underpinned current knowledge. In this way these boxed sections provide students with a taste (albeit a limited one) of the kind of research methods and details they can expect to encounter in more detailed studies of each of the subdisciplines of human movement studies. Such studies are undertaken typically in the second and subsequent years of formal courses in human movement studies. The boxed sections contain research examples from around the world. This was done deliberately to both highlight the importance of positioning research and knowledge in a relevant social content and to illustrate the genuinely international nature of research activity in our field.

As the title of this book indicates, our intention in writing this book has been to provide an introduction to the biophysical fundamentals of human movement. We have, therefore, by necessity, deliberately tried to provide a coverage of the topic that is broad and illustrative rather than detailed and exhaustive. An in-depth coverage of each of the biophysical subdisciplines is clearly well beyond the scope of this text and students with an interest in more detailed study in any of the areas should be directed to the many excellent specialised texts now available for each of the subdisciplines. (A number of these are detailed in the Further Reading listings that follow each of the major sections within this book.) We have also deliberately restricted our coverage within the book to the biophysical foundations of human movement and have not attempted coverage of the equally important sociocultural subdisciplines of human movement studies, such as social psychology, history, philosophy, pedagogy and sociology. These are the focus of a companion text, *The Sociocultural Foundations of Human Movement*.

The study and understanding of human movement present an exciting challenge for students, scientists and practitioners alike. Given how central an understanding of human movement and its enhancement is to a wide range of human endeavours, it is our hope that *The Biophysical Foundations of Human Movement* will serve as a readable introduction for both students and professionals involved in sport and exercise science, physical education, kinesiology, ergonomics, music and performing arts, physiotherapy, occupational therapy, nursing, medicine, health education and health promotion and other rehabilitation and health sciences, and will help to convey to our readers some of the magnetism that this subject matter holds for us.

Acknowledgments

Our sincere appreciation is extended to a number of people, without whose contribution this book could never have been completed. In particular we wish to express appreciation to:

- Louise Blood, for the excellent original drawings and artwork throughout the book
- Scott McLean, for the remaining graphical illustrations
- Judy Land, Jan Holmes and Debbie Noon for typing the majority of the manuscript
- Frank and Janet Pyke, for early discussion about the structure of the text and for

arranging contact with our initial publisher, Macmillan Education Australia
- David Aitken, Don Bailey, Robin Burgess-Limerick, Richard Carson, Bob Faulkner, Mark Forwood, Holger Gabriel, Piero Giorgi, David Jenkins, Mariken Leurs, Ian Jobling, Stephan Riek, and Wally Wood for supplying information and constructive commentary on sections of the book
- Macmillan Education Australia and especially Publishing Director, Peter Debus, for their patience and expertise throughout the whole writing and production stage of the original version of this book
- Rainer Martens and his staff at Human Kinetics, who skilfully aided in the transformation of an Australian text into an international one
- Our families, friends, and colleagues for their support, understanding, and tolerance while this book was being written.

The introductory chapters (Chapters 1 and 2) plus Chapters 16–19 were written by Bruce Abernethy; Vaughan Kippers wrote Chapters 3–6; Rob Neal Chapters 7–11; Laurel Mackinnon Chapters 12–15; and Stephanie Hanrahan Chapters 20–23.

Some Notes for North American and European Readers

The Biophysical Foundations of Human Movement was originally published by Macmillan Education Australia and was written with the Australian context and Australian readers in mind. In revising the book for distribution by Human Kinetics throughout Europe and North America, we have been conscious of the need to use terms and examples which are universally understood; at the same time, we remain cognisant that some terms will nevertheless convey somewhat different meanings to readers from different parts of the world.

To assist readers from other cultures, we have prepared (below) a brief explanation of some general Australian terms and expressions that appear within the book but which may have subtly different meanings for either North American or European readers. We trust these explanations are useful.

Disciplinary and Professional Terms

We use the term *human movement studies* to refer to the body of knowledge or discipline concerned with human movement. Many North American readers will be more familiar with the synonymous term *kinesiology*. Likewise North American readers may wish to substitute the term *physical therapy* for *physiotherapy* at various points in the text.

Some Sporting Jargon

Given the nature of our subject matter, we make frequent use throughout the text of examples from sport to illustrate some basic biophysical phenomena of movement. Terms associated with sport are much more culturally-specific than scientific terms. For example, any reference we make throughout the text to *training* should be considered to encompass not only physical conditioning but also skill practice.

Where we refer to *football* and *football codes* readers may wish to consider any of the sports of soccer, American football, Gaelic football, Australian football, rugby union, or rugby league; when we refer to *hockey* we intend reference to field hockey rather than ice hockey; and when we make reference to *basketballers* and *footballers* we mean basketball players and football players. By *social sport* we refer to recreational sport.

Finally, when we use examples from *cricket* and *netball* we are referring to sports which will be familiar to residents of former British Commonwealth countries but relatively few others. Cricket is a sport that requires the player to accurately hit (with a bat) a fast moving, bouncing ball about the same size as a baseball, while netball is a team sport broadly similar to basketball but with much tighter rules constraining player and ball movement.

Contents

PART 1

Introduction to human movement studies

CHAPTER 1

Human movement studies as a discipline and a profession

- What is human movement studies and why is it important?
- What are disciplines and professions?
- Is human movement studies a discipline?
- How might a discipline of human movement studies be structured?
- What should the discipline of human movement studies be called?
- Professions based on the discipline of human movement studies
- Relationships between the discipline and professions

The purpose of this chapter is to:

- provide a definition and description of the field of human movement studies
- draw distinction between the discipline and the professions of human movement studies
- examine the justification for, and possible structure of, a discipline of human movement studies
- examine briefly the vexing question of what the discipline of human movement studies should be most appropriately called
- examine what is meant by the terms multidisciplinary, interdisciplinary and crossdisciplinary
- introduce the major professions and professional associations relevant to human movement studies
- explore (desirable) relationships between disciplines and professions.

What is human movement studies and why is it important?

Human movement studies is the comprehensive and systematic study of human movement. It is that field of academic inquiry concerned with understanding how *and* why *people move and the factors that limit and enhance our capacity to move.*

Two key points need to be emphasised within this very simple definition of the field of

human movement studies. The first is that the unique focus of the field is on human movement. This is true regardless of whether the movement to be ultimately understood is one performed, for example, in the context of undertaking a fundamental daily skill (such as walking, speaking or reaching and grasping), executing a highly practised sport or musical skill, exercising for health, or regaining the function of an injured limb. The study of human movement is important in, and of, itself, as movement is a central biological and social phenomenon.

The study of movement is central to the understanding of human biology as movement is a fundamental property, indeed indicator, of life (remembering that biology is literally the study of life). Human movement, as we have noted in the preface, offers a valuable medium for the study of biological phenomena fundamental to developmental changes across the lifespan (changes that occur with ageing as a consequence of internal body processes), to adaptation (changes that occur as an accommodation or adjustment to environmental processes) and to the interactions of genetic and environmental factors (nature and nurture) that dictate human phenotypic expression.

Human movement, especially that which occurs in collective settings such as organised sport, exercise settings and health and physical education classes, also clearly has an essential social and cultural component, which also warrants its intensive study. Understanding individual and group motives and opportunities and barriers to involvement in different types of human movement, for instance, provides an important window into the nature of human society just as understanding the mechanisms of individual human movement provides an important window into the understanding of human biology. Movement, in short, plays a fundamental role in human existence and what it means to be human and for these reasons warrants our very best efforts to understand it.

The second key point that needs to be highlighted within our definition of human movement studies is the importance of a systematic, research-based approach to the generation of knowledge. As many aspects of the current practice of human movement involve practices based as much on fads, folklore, tradition and intuition as on sound, logical theory substantiated by systematically collected, reproducible data, it is imperative that the knowledge base for human movement studies be one based on research conducted with a methodological rigour equivalent to that of other established biological, physical and social sciences. Only through such an approach can fact be separated from fiction and a sound basis for best practice in the profession, based on the knowledge base of human movement studies, be established.

In the true tradition of the scientific method the field of human movement studies aims to not only describe key phenomena from within its domain but also to move beyond description to understanding through explanation and prediction. Human movement studies, as a systematic field of study, thus carries the twin goals of all fields of science, namely the generation of knowledge through understanding of basic phenomena, and the application of knowledge for the benefit of society. The basic understanding of human movement, for which the field strives, has applicability to all of the many areas and professions that deal with the enhancement of our capacity to move and to adopt healthy lifestyles. Obvious areas of application of the knowledge base of human movement studies are to sport, exercise, health and physical education, the workplace and rehabilitation; obvious professions that rely on such information include professionals in the health and fitness industry, sports scientists, physical educators, health promoters, doctors, nurses, and therapists.

Given that knowledge about human movement is clearly important in its own right as well as in its application to the practice of many professional groups, an important question that follows is 'how is knowledge about human movement organised and how is this knowledge translated into the practices of relevant professions?'. Answering such a question requires consideration of the discipline and professions of human movement studies.

What are disciplines and professions?

According to the pioneering American physical educator Franklin Henry:

> . . . an academic discipline is an organized body of knowledge collectively embraced in a formal course of learning. The acquisition of such knowledge is assumed to be an adequate and worthy objective as such, without any demonstration or requirement of practical application. The content is theoretical and scholarly as distinguished from technical and professional.
>
> *(Henry 1964)*

The principal function of a discipline is therefore to develop a coherent body of knowledge that describes, explains and predicts key phenomena from the domain of interest (or subject matter).

In contrast, professions, as a general rule, try to improve the conditions of society by providing a regulated service in which practices and educational/training programs are developed that are in accordance with knowledge available from one or more relevant disciplines. Practice in the profession of engineering, for example, is based on application of knowledge from disciplines such as physics, mathematics, chemistry and computer science, and practice in the medical profession is based on knowledge from disciplines such as anatomy, physiology, pharmacology, biochemistry and psychology. Established professions share a number of characteristics including:

- an identified set of jobs or service tasks over which they have jurisdiction
- organisation under the framework of a publicly recognised association
- identified educational competencies and formalised training and education criteria
- political recognition, usually through acts of government legislation
- a code of ethics defining minimal standards of acceptable practice.

Disciplines therefore seek to understand subject matter and professions to implement change based on this understanding. The emphases within disciplines and professions are often characterised as theory/research versus application/practice but such a distinction is overly simplistic and potentially misleading. Applied research (including research on aspects of professional practice) is now an accepted part of the business of the discipline just as the profession may frequently be the site for original research.

Is human movement studies a discipline?

Remembering our earlier definition of human movement studies and Henry's definition of a discipline, an important practical as well as philosophical question is whether there is a unique, organised body of knowledge on how and why people move (to satisfy the criteria for a discipline of human movement studies) or whether human movement studies is simply the application of knowledge from other disciplines, such as anatomy, physiology and so on (thereby making it, by definition, more a profession than a discipline)? This question has been the source of much debate both within and beyond the field for at least the past three decades, with the extent of the uniqueness and collective coherence of the knowledge within the field being the source of most contention. The establishment of university departments of human movement studies (or the like), independent of traditional professions such as physical education teacher training, is predicated on the assumption that human movement studies possesses an organised body of knowledge in much the same way as do 'traditional' disciplines such as physics, chemistry and psychology and that human movement studies is more than simply a loose collection of the applications of knowledge from other fields.

The foreparents of the modern field of human movement studies were, as we will see in the next chapter, primarily physical educators. A number of these, most particularly the

physiologist/psychologist Franklin Henry and the motor developmentalist Lawrence Rarick, created strong arguments in the 1960s for both the importance and the existence of a discipline of human movement studies, claiming that such a field (or its precursor physical education) asked questions that would not have arisen from the cognate (parent) disciplines.

Rarick, in a paper in the journal *Quest*, argued that:

> ... most certainly human movement is a legitimate field of study and research. We have only just begun to explore it. There is need for a well-organised body of knowledge about how and why the human body moves, how simple and complex motor skills are acquired and executed, and how the effects (physical, psychological and emotional) of physical activity may be immediate or lasting.
>
> *(Rarick 1967)*

In a similar vein, Henry, in a much-quoted 1964 paper, claimed the pre-existence of a discipline base for the study of human movement. Henry wrote then that:

> ... There is indeed a scholarly field of knowledge basic to physical education. It is constituted of certain portions of such diverse fields as anatomy, physics and physiology, cultural anthropology, history and sociology, as well as psychology. The focus of attention is on the study of man as an individual, engaging in the motor performances required by his daily life and in other motor performances yielding aesthetic values or serving as expressions of his physical and competitive nature, accepting challenges of his capability in putting himself against a hostile environment, and participating in the leisure time activities that have become of increasing importance in our culture.
>
> *(Henry 1964)*

Henry's definition of the discipline base of our field has generally stood well the test of time save for some relatively minor changes, most obviously: (i) the substitution of the term human movement studies for physical education (now typically defined in a narrower professional sense), (ii) the extension of the focus of the field beyond solely the study of the person as an individual to also incorporate the study of the person as an element of a social system, and (iii) the alteration of the language of expression to recognise the equal applicability of the knowledge base to females as to males.

How might a discipline of human movement studies be structured?

If we consider again our earlier definition of human movement studies as that field concerned with understanding how and why people move and the factors that limit and enhance our capacity to move it becomes apparent, in keeping with Henry's propositions, that a human movement studies discipline must include selected aspects of a broad range of other disciplines and discipline groups. This follows because movement potential and performance are known to be influenced by, among other things, biological factors such as maturation, ageing, training and lifestyle; health factors such as disease, disuse and injury; and social factors such as motivation, incentive and opportunity. A discipline of human movement studies must therefore draw heavily, but not exclusively, on the methods, theories and knowledge of a wide range of other disciplines and provide them with an integrative focus on human movement. Information of relevance for a discipline of human movement studies may be gleaned from biological science disciplines such as anatomical science, physiology and biochemistry; physical science disciplines such as physics, chemistry, mathematics and computer science; social science disciplines such as psychology, sociology and education; and disciplines in the humanities such as history and philosophy.

Figure 1.1 presents one possible way of conceptualising the organisation of knowledge within a discipline of human movement studies. In this conceptualisation the discipline of human movement studies consists of the collective knowledge contained within and between each of the subdisciplines of functional anatomy,