CLINICAL BIOMECHANICS
Musculoskeletal Actions and Reactions

R. C. Schafer, D.C., F.I.C.C.

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FOREWORD

At last a book has been written for the general practitioner and advanced student that presents a basic understanding of the biomechanical approach to structure and function. Until now, our education has lacked any single composite source upon which to draw information with regard to our everyday commitment to musculoskeletal problems.

Unfortunately, much of our present knowledge is enmeshed in mathematical and engineering complexities that are irrelevant to the practitioner. *Clinical Biomechanics* allows us to apply biomechanical principles to common traumatic, pathologic, and postural disorders of the spine and extremities, and explains how these principles can be applied to speed patient recovery and rehabilitation. In essence, it offers a compendium of fundamental concepts that should be applied daily, as well as offering a basic understanding to comprehend more sophisticated literature.

This book presents information that allows doctors to review their personal approaches toward their treatment methods. It poses the questions: Does my method agree with current biomechanical principles? Are my results or failures occurring for the reasons I think they are?

We owe a great debt of gratitude to the author, Dr. Richard C. Schafer, who dedicated thousands of hours researching basic principles from over 500 books and technical papers. His ability to present this information in simple language and to unify rather than separate structure from function, as is routine in many orthopedic texts, should be welcomed throughout the health care field.

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PREFACE

Clinical biomechanics has been a subject of interest within the chiropractic profession since its inception. In some instances within pioneer chiropractic, it was applied in a limited fashion as a logical approach to a mechanical problem. The historic writings of Carver, Reeves, Budden, Steinbach, Logan, Weiant, Grecco, Illi, and many others affirm this fact. During the last decade, this interest has been rapidly increasing on a much more sophisticated level, yet there has been little reliable literature available within the profession outside of specific papers on limited subjects.

For various reasons, much of the contemporary information pertinent to the biomechanical aspects of patient care has not been published in a readily available form. Most data have been brought forth in seminars or in technical bulletins and professional papers that were not widely distributed. In addition, considerable information important to general practice had to be sifted from literature aimed at the reconstruction surgeon or the prosthetic bioengineer. It is for these reasons that this book was initiated.

When biomechanical principles are incorporated into health care delivery, the physician has a clearer understanding of the muscular, skeletal, and articular components of the musculoskeletal system, its mechanisms, and how they determine gross human action and reaction. This requires analysis of both the internal specific and the external general aspects, an understanding of the mechanical principles involved, how they are influencing the person as a whole, and how the patient is adapting to these forces. Thus:

An understanding of clinical biomechanics is essential to the diagnosis and scientific application of adjusting fixed articular disrelationships and correcting those forces that tend to maintain abnormal musculoskeletal disorders and their neurologic, circulatory, and lymphatic ramifications.

This book for general practitioners and advanced students incorporates a practical state-of-the-art compilation of applied biostatics, biodynamics, kinesiology, kinematics, kinetics, and the related sciences to serve as a basis for clinical application and research. Emphasis is on the cause of articular disorders, the mechanisms involved, why they occur, how they interact, and how they can be corrected. This is not to say that physiatrists, osteopaths, physiotherapists, bioengineers, physical education students, and other members of the allied health sciences will not find many sections of extreme value in their respective disciplines.

The goal has been to offer a useful presentation for those who have a special health care interest in the neuromusculoskeletal system but do not have a broad background in physics, let alone biophysics, so that the "bottom line" conclusions of reliable research may be directly applied in patient care. Thus, advanced engineering language and the computation of mathematical equations of little usefulness to the clinician have been avoided. Great concern has been given to cause-and-effect principles rather than the solving of theoretical situations through geometric designs and trigometric functions. For ease in comprehension, subjects are discussed from the general to the specific and from the simple to the more complicated whenever practical.

This is the first comprehensive text on this subject matter developed specifically for chiropractic physicians and the first such text to incorporate the findings of several chiropractic researchers in an orderly and sometimes comparative fashion. The research conclusions of scores of well-known figures and institutions within the profession are included with those of prominent orthopedic researchers in North America and Europe. It is also unique in that the book's Editorial Review Board incorporates representatives from the majority of recognized American chiropractic colleges to portray a wide scope of contemporary thought.

The text elucidates the role of biomechanics in the evaluation of numerous neuromusculoskeletal disorders and the anatomic basis of their conservative management. The discussions concentrate on essential clinical information primary to an understanding of biomechanical implications and applications. To make such an emphasis possible, pertinent mechanical laws and principles are included that are thought to be of value from a general education standpoint, without striving to weight the text with sometimes complicated physics that would be of interest only to the researcher.

The text is divided into three parts. Part I introduces the basic principles of clinical biomechanics and incorporates five chapters which offer a review of the pertinent basic sciences, mechanical terms, biodynamic principles, factors of clinical stability, static and dynamic postures, and the basic neuromuscular considerations involved in clinical application. These chapters have been designed to give the reader a fundamental and concise explanation of body structure, mechanical functions, kinematics, myokinetics, mechanical stress, tissue properties and responses, and their respective roles in clinical application. The emphasis is on systemic and multiregional considerations that do not easily fall into a regional category. The chapter on basic neuromuscular considerations is unusual in typical books on biomechanics, but it is vital in clinical practice to grasp the importance of the nervous system in holistic structural control. In health care, it would be folly to attempt to separate our understanding of function from structure *in vivo*.

Part II, the core of the text, discusses in four chapters the biomechanical marvel of the human spine and pelvis. This part is introduced by a basic discussion of the general aspects of spinal biomechanics, which is followed by specific chapters on the cervical region, thoracic region, and the lumbar spine and pelvis. Herein, the practical application of biostatics, the science of the relationship of structure to function, is emphasized along with the biomechanical aspects of the resolution of common clinical problems.

Part III presents in two chapters the basic biomechanical factors of the upper and lower extremities. The emphasis here is on regional structure, kinesiology, biomechanical tests, and common clinical problems.

Rather than burden the book with numerous footnotes and reference numbers to multiple data sources, only the original author's name is mentioned in the text to guide the reader to the complete source in the bibliography. For rapid reference to specific points, a comprehensive index has been included.

Those of us who have been involved in the development of this book trust that this compilation will aid the reader in studying and treating the human body with greater insight.

—RCS

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Deep appreciation is expressed to the members of the chiropractic educational community as well as scores of reputable practitioners and independent researchers. Because of their specialized ability and acknowledged expertise, the scope of this text has been enhanced by their contributions to the basic manuscript and their constructive review refinements.

While space does not allow mention of all contributors and reviewers, special gratitude must be extended to the following, in alphabetical order:

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PART 3: CLINICAL BIOMECHANICS OF THE EXTREMITIES

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Part 1

BASIC PRINCIPLES OF CLINICAL BIOMECHANICS

CHAPTER 1

The Human Machine

In the study of clinical biomechanics, one should first be aware of the basic holistic, osteologic, arthrologic, and myologic factors involved, as well as the basic anthropometric systems frequently utilized. This chapter reviews these factors from their basic aspects so that it will be obvious that clinical biomechanics encompasses knowledge of a wide variety of related sciences.

Chiropractic's approach in health care is to establish and maintain optimal physiologic activity by correcting abnormal structural relationships. Its goal is to organize the body in such a manner as to enable it to utilize its own biologic resources for a return to normal function. To this end, a thorough knowledge of clinical biomechanics is invaluable.

INTRODUCTION

Traditionally, although not limited to such, chiropractic health care is associated with the detection and correction of disrelated segments of the skeletal system, especially those of the spinal column and pelvis. As the chiropractic profession has evolved during this century, it has become increasingly evident that disrelated structures, particularly certain spinal disorders, are a prime source of disturbance to the neurologic bed and constitute a threat to health that must not be ignored. Proper correction requires the careful blending of data gathered from a variety of specialized sciences so that practical applications can be made in a holistic manner.

Holistic Considerations

The musculoskeletal system can narrowly be looked at as a machine capable of performing mechanical work through its system of muscular forces, bony levers, centers of joint rotation, and body segements which provide weight and mass. In the study of biomechanics, there is a tendency to decompose a system and look at its parts in isolation—the skeletal system alone can be thought of as a system of interconnected links. While this approach is helpful in specific biomechanical problem solving, such a purely mechanical concept is an oversimplification that is dangerous in health care. A far more holistic approach is necessary. The human body is not an object that accidentally gets disassembled and requires assembling.

Holism is the theory that the determining factors in nature as a whole are not reducible to the sum of their parts. A human being is still a mystery even after we add up all his or her tissues, organs, and systems in the laboratory. Chiropractic has recognized this in its approach to health care. Unfortunately, there is an inherent danger in allopathic specialized health care in becoming "part" oriented. This danger must be avoided in chiropractic in any study or application of biomechanics. Our skeletal structure is more than an osseous cage to hold our vital organs or a bony hatrack on which nature has hung our muscles. Our muscles are more than pulleys, our nerves are more than wiring, and our vessels are more than fluid conduits. A person is more than an assortment of independent organs or a maze of sovereign systems. An individual is a carefully integrated biologic unit, not just the sum of its parts.

From birth, the human as a biped enjoys an architectural opus magnum which allows for agility, strength, leverage, mobility, and balance against gravity's constant pull. When normal biomechanics are disturbed even slightly, distortion results because of the intricate interrelationship of our structural and functional systems. Adaptation to stress depends upon the unifying, coordinating, and controlling forces within the body—the sum of *all* body systems, either directly or indirectly. Any dysfunction of one system may have a far-reaching effect upon the nervous system because of the inherent relationship between structure and function. As structure cannot be separated from function, neither should health care fail to recognize the body's complex unification (Fig. 1.1). The term *biostatics* refers to the science of the relationship of structure and function.

There is another inherent danger in health care—to think of structure solely in its static sense, as shown on a textbook page. For example, and far too often, some think of the spine as a flexible rod that moves only on the command of will. Yet, humans are dynamic creatures, structurally as well as functionally. Body movement never ceases; motion is constant. With every breath, the

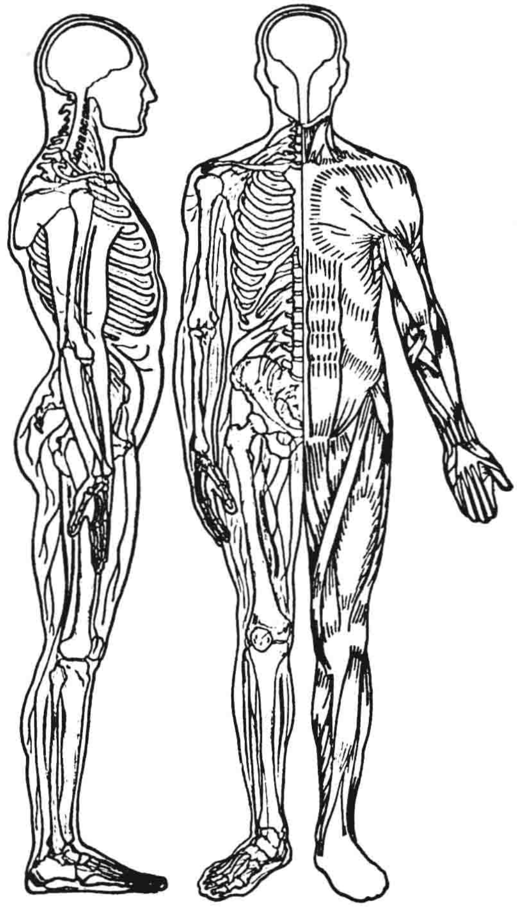

Figure 1.1. Artist's rendering of the overall relationship of the musculoskeletal system.

skull, spine, pelvis, ribs, and attachments are in motion. Add this minimal motion to the gross movements of daily living, and we can appreciate the persistent motion, constant stress, and necessity for proper alignment. Mechanically, physiologically, and psychologically, the human body is compelled to struggle for a state of structural and functional equilibrium.

Related Sciences and Studies

Although the relationship of biomechanics to biodynamics has been emphasized by the chiropractic profession for almost a century, there is a continual need for more objective research to support clinical observations. Such research must incorporate the principles of several areas of related study.

BIOMECHANICS AND ASSOCIATED STUDIES

A knowledge of either spinal or extravertebral joint action requires an understanding of such factors as power sources, segment speed and acceleration, axes and planes of motion, mass direction, leverage, muscle-length-tension relationships, and the neuromotor and sensory feedback integrative mechanisms.

Mechanics (the science of force and matter) is the study of forces and the effects of these forces. The terms biomechanics or bioengineering refer to these principles as applied to an organism at rest or during movement, incorporating the principles of engineering, anatomy, and physiology toward health care goals. That is, *biomechanics* is the study of mechanical forces as they are applied to a living organism (bion), including those forces which arise internally or externally to the body. The general application of physical laws and theories to life force (bionergy), processes, and functions is called *biophysics*, while the science pertinent to life processes is referred to as *bionomy*. The general term of *biotics* is used to describe the science which deals with the functions and qualities of life.

In recent years, the term *bioengineering* has been restricted to the research and development of mechanical devices such as artificial parts, cardiac pacemakers, hearing aids, etc. Especially when such devices are computerized, the term *bionics* is used to describe the research, study, and application of such sophisticated apparatus. *Biometrics*, another related science, is the study of mathematics, statistics (biometry), and vital statistics (biostatistics) as applied to the analysis and solution of problems arising in the health sciences.

KINESIOLOGY AND ANTHROPOMETRY

The broad term *kinesiology* (the study of muscles and muscular contraction) refers to the science of movement, particularly human movement and human movement problems. This encompasses all factors which influence or are influenced by movement. Such study is supported by such sciences as human anatomy and anthropometry.

Anthropometry, the science of measuring the human body, often utilizes such factors as height, gross size, weight, skin fold thickness, osteometry, craniometry, physique, body and part proportions, and segmental lengths and circumferences.

BIODYNAMICS

Mechanics. The study of mechanics can be subdivided into two broad categories: statics and dynamics. The term *statics* refers to the study of bodies at rest or in equilibrium, whereas the study of *dynamics* is concerned with bodies in motion. The more restrictive term *biodynamics* refers to the scientific study of the nature and determinants of an organism's behavior during motion. Biodynamics can be subdivided into three categories: kinematics, kinetics, and kinesics.

Kinematics. Human kinematics (the science of body motion) is that part of biomechanics concerned with the possible motions of a body part. While not considering the forces involved in producing motion, kinematics deals with the various geometric relationships that exist among accelerations, velocities, and displacements during motion. Kinematics, for example, describes body segment displacement (flexion, abduction, etc.), ranges of motion, and patterns of movement during motion such as of the ankle, hip, and spine. A kinematic study is performed when, for instance, such principles are applied to the analysis of scoliotic displacement.

Kinetics. The scientific study of the rate of change of a specific factor in the body is called *kinetics*. It is the study of the relationship between a force acting upon a body or body segment and the changes produced in body motion. In other words, kinetics is concerned with moving bodies and the forces that act to cause motion. It is commonly expressed as amount per unit of time. Kinetics, as contrasted to kinematics, analyzes forces such as those of muscles, gravity, and surface reactions that are involved in body propulsion, coordination, and segment displacement. For example, a kinetic study is performed when such principles are applied to analyze the forces necessary to change a scoliotic spine to a more normally aligned spine.

Kinesics. This field studies the body and its static and dynamic positions as a means of communication (body language). Body language is one's subconscious use of gestures, posture, and other forms of nonverbal expressions in communication. Its clinical application is found in diagnosis (gross inspection) and psychology. The form of kinesics most utilized in applied biomechanics is that of kinematography, where the human form is analyzed during motion by such methods as photographic "stills."

CLINICAL APPLICATION

In traditional medical practice, the musculoskeletal system is the most overlooked system in the body, yet it contains over half the body mass. The relationship between structure and function, and the interrelationship between all body systems, cannot be denied. Muscles, bones, and connective tissues are involved in both local and systemic pathology and in a wide assortment of functional and referred disturbances. Thus, great care must be taken in eliciting the details of a complaint when any musculoskeletal disorder is suspected.

An understanding of kinesiology and its related sciences helps the physician to better appreciate and analyze individual motor

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