KINESIOLOGY

Fifth Printing

KINESIOLOGY

OF THE HUMAN BODY

Under Normal and Pathological Conditions

By

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CHARLES C THOMAS · PUBLISHER

Springfield · Illinois · U.S.A.

Published and Distributed Throughout the World by

CHARLES C THOMAS • PUBLISHER
BANNERSTONE HOUSE
301-327 East Lawrence Avenue, Springfield, Illinois, U.S.A.

ISBN 978-0-398-01846-7 (hard) ISBN 978-0-398-01846-6 (paper)
Library of Congress Catalog Card Number: 55-6121

First Printing, 1955
Second Printing, 1964
Third Printing, 1970
Fourth Printing, 1973
Fifth Printing, 1977

Printed in the United States of America

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To my good Wife and Helpmate
Louise Steindler

PREFACE

A PREVIOUS publication on the subject of the *Mechanics of Normal and Pathological Locomotion,*[1] has met with what the author believes to be an indifferent reception. There seemed to be two reasons for it. The first problem was that not enough consideration had been accorded to the practical application of rehabilitation and re-education of locomotor deficiencies. With this in mind, the author has endeavored to give the theoretical facts a much wider interpretation in connection with diagnostic and therapeutic questions, fully realizing that the value of the book lies in what help it can offer to clinician and physical educator.

The other criticism was that the analysis of locomotion has ventured too much into the field of general mechanics which made the reading of the book uncomfortable and required much needless concentration. It was argued that practical conclusions could be attained more directly by observation and empiricism without any tedious theoretical preambles. It is with this second argument that the author has to disagree. He is neither willing nor able to reconcile himself to a short cut method based entirely on impressions and to summersault over the hard facts of basic sciences just in order to arrive at quick and usually superficial practical conclusions.

He is convinced that Kinesiology is an indispensable background for the prevention, the treatment, and rehabilitation of locomotor disorders.

On the other hand, it is conceded that mathematical accuracy in the calculation of locomotor events is only too often swallowed up by the stream of physiological and especially of pathological fluctuations; that certain allowances must be made because no two situations, be they normal or abnormal, are so alike that they can be expressed accurately by the same mathematical formula.

After all the analysis of human motion is primarily the job of the biologist, and only secondarily that of the physicist or engineer. The purely mechanical aspect of locomotion, which is the province of kinesiology, is merely a part of the physiology of motion in general.

All motor events are the end result of a long chain of cause and effect, the beginning of which, as in all things, is steeped in mystery. The study of kinetics taps this chain of events at a point just behind the clinical manifestation while the biologist tries to penetrate much farther into the background. In other words, kinetics explains only the physical events which lead immediately to the locomotor performance and it is not concerned with the more remote causes of human motion.

[1] Steindler, A.: Charles C Thomas, Publisher, Springfield, Illinois, 1935.

With these considerations in mind the author has tried to reduce all mathematical calculations to a minimum and has advanced on every occasion the clinical significance and the practical implication of kinetic findings. This, he hopes, should make for more palatable reading.

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ACKNOWLEDGMENTS

THE author has received most valuable assistance in the preparation of this book. He is particularly grateful for the help extended to him by his associate, Dr. Webster B. Gelman. He not only furnished the illustrative drawings but he also helped with the arrangement of the book and with reading of the text, for which he made many useful suggestions. For the clerical help in typing the text the author is indebted to Mrs. June Clendenin, Mrs. Marian Heilbrun, and Mrs. Margaret Washburn. The photographic work was in the able hands of the Messrs. Kent. Mrs. Thea Wiegand compiled the table of contents and author and subject indices. The publisher, Mr. Charles C Thomas, has bestowed upon this work his highly appreciated painstaking efforts in the examination of the text, its editing and printing. All of this assistance is hereby thankfully acknowledged by the author.

A. STEINDLER

CONTENTS

Part II

THE TRUNK

LECTURE IX. THE MECHANICS OF THE SPINAL COLUMN

LECTURE X. THE DYNAMICS OF THE NORMAL SPINE

LECTURE XI. THE PATHOMECHANICS OF THE LUMBOSACRAL JUNCTION

LECTURE XII. THE NORMAL AND PATHOLOGICAL MECHANICS OF THE PELVIS

LECTURE XIII. THE MECHANICS OF RESPIRATION, INTRODUCTION AND DEFINITION

LECTURE XIV. THE MECHANICS OF POSTURE

LECTURE XV. THE PATHOMECHANICS OF SCOLIOSIS

Part III

THE EXTREMITIES

LECTURE XVI. MECHANICS OF THE HIP JOINT

LECTURE XVII. THE PATHOMECHANICS OF THE STATIC DISABILITIES OF HIP AND PELVIS

LECTURE XVIII. THE PATHOMECHANICS OF THE PARALYTIC HIP JOINT

LECTURE XIX. THE MECHANICS OF THE KNEE JOINT

LECTURE XX. THE PATHOMECHANICS OF STATIC DEFORMITIES OF THE KNEE JOINT

LECTURE XXI. THE PATHOMECHANICS OF THE PARALYTIC KNEE

LECTURE XXII. THE MECHANICS OF FOOT AND ANKLE

LECTURE XXIII. THE PATHOMECHANICS OF THE STATIC DEFORMITIES OF FOOT AND ANKLE

LECTURE XXIV. THE PATHOMECHANICS OF THE PARALYTIC FOOT AND ANKLE

LECTURE XXV. THE LOWER EXTREMITY AS A WHOLE

LECTURE XXVI. MECHANICS OF SHOULDER-ARM COMPLEX

LECTURE XXVII. THE PATHOMECHANICS OF PARALYSIS OF THE SHOULDER

LECTURE XXVIII. THE MECHANICS OF THE ELBOW JOINT

LECTURE XXIX. THE PATHOMECHANICS OF THE PARALYTIC ELBOW

LECTURE XXX. MECHANICS OF HAND AND FINGERS

LECTURE XXXI. THE PATHOMECHANICS OF PARALYSIS OF HAND AND FINGERS

LECTURE XXXII. THE ARM AS A WHOLE

LECTURE XXXIII. SPRAINS OF THE JOINTS OF THE UPPER EXTREMITY

LECTURE XXXIV. THE PATHOMECHANICS OF SPRAINS OF THE LOWER EXTREMITY

LECTURE XXXV. THE PATHOMECHANICS OF THE MORE COMMON FRACTURES OF THE UPPER EXTREMITY

LECTURE XXXVI. THE PATHOMECHANICS OF THE MORE COMMON FRACTURES OF THE LOWER EXTREMITY

PART IV

THE GAIT

LECTURE XXXVII. ON THE MECHANICS OF THE GAIT

LECTURE XXXVIII. THE PATHOMECHANICS OF THE GAIT

KINESIOLOGY

Part I

GENERAL KINETICS

Lecture I

THE AIMS AND PURPOSES OF KINESIOLOGY

KINESIOLOGY is that part of physiology of motion which describes and analyzes locomotor events so far as they reflect the action of mechanical forces. In other words, it presents bodily motion as a special case in mechanics.

The question is, can it be so represented; can human motion, with its boundless variability and being the product of a multitude of only partially known factors, be forced into the narrow frame of precise and austere mathematical and physical laws?

This is the very point which ultimately decides whether or not there is enough practical value in the undertaking to warrant this line of investigation. It must be admitted that locomotion involves certain unknown and incalculable factors which preclude a strictly mathematical presentation.

Nevertheless, the operation of known physical laws can be clearly recognized and evaluated in properly observed locomotor events. The Newtonian laws are accepted as being fundamental for terrestrial mechanics. We intend to interpret the operation of these laws in terms of human motion. We do not attempt to formulate general mechanical laws from our observation as Newton formulated his law of gravitation from observing the falling apple. In other words, our reasoning is *deductive* from the accepted mechanical laws to their interpretation in terms of our observations; it is not *inductive* from the observation to the formulation of the laws.

If we are in error the quarrel is with the observation and its interpretation and not with the law itself. The danger then lies not in failing to recognize that a mechanical law is operating but rather in overlooking the existence of other laws, not mechanical in nature, which have their share in human locomotion.

A good example is the interpretation of the functional adaptation of bone as formulated by Julius Wolff in 1876. When it was recognized by Culman that the internal structure of the upper end of the femur presents a perfectly calculated construction of a loaded crane, it was believed that the physical laws had absolute and complete control over the form and texture of the human bone and that the lamellar arrangements or trajectories, as they are called, fall strictly in line with tension and pressure stresses. This is no doubt true to a large extent. The only mistake was that the operation of other laws biological in nature had been overlooked because their influence on the structure of the bone was less evident. As a matter of fact, the architectural response of bone to the mechanical forces of stress and strain merely approaches but never completely conforms with the accurate engineering calculation. The reason is that there are other biological laws in operation which, under certain conditions, may become more conspicuous than the mechanical laws themselves. For instance, the organization of bone after fracture may proceed under the laws of transformation on stress and strain resistance. But it would be more difficult to demonstrate the same law of functional adaptation in cases of severe osteomalacia or in severe rickets.

This is merely one of the many situations in which biological factors may take precedence over mechanical ones.

The apparent discrepancy which exists between the biomechanical laws of Hueter-Volkmann and those of Wolff and Roux is another illustration. The former stipulates that pressure produces bone atrophy, the latter that it leads to bone formation. The fact is that under pressure both bone production and bone atrophy may occur as the degree and duration of stress varies and as the resistance to pressure fluctuates under the biological influence of growth and maturity. When Scaglietti in 1930 examined the effect of pressure on the growing femur, he found that the epiphyseal cartilage responded with arrest of bone growth despite a marked proliferation of cartilage cells. Such an arrest must be interpreted as the result of excessive and continuous pressure at the time when the growing bone shows marked biological activity and when it is therefore much more vulnerable than resting bone. Such instances reveal how fallacious it would be to explain morphological phenomena of the locomotor system purely in terms of mechanical laws.

With all these complicating influences at work, how can it still be maintained that locomotion is a special case of mechanics? Is it possible to analyze and calculate human motion on similar lines as we calculate the movement of an inert mechanical device?

Our contention is that this is indeed possible under certain reservations; and the question now arises whether the concessions which must be made to mathematical accuracy are so far reaching as to make the value of calculations illusory or whether they are still within acceptable limits of accuracy.

Here are some of the principal concessions to be made.

1. In human locomotion we are dealing with bodies and parts of irregular morphological shapes composed of tissue of varying density and specific gravity for which data regarding weight, volume, center of gravity and inertia must be established. To do that one must approximate the human body or its part to standard geometrical forms of homogeneous structure. The arm is considered as a cylinder, as is the trunk, the whole extremity as a truncated cone, the head as a sphere and so forth. The inertia of the body or its parts which resists rotatory motion is then calculated on this basis.

2. Although we know that the different systems of the bones, muscles, and so forth, are not of uniform density, we accept an average density without great loss of accuracy.

3. We know that the rotatory moment produced by muscle contraction depends upon the angle of application of the muscle to the bone and that this angle changes with the position of the joint; we further know that with increasing contraction the tension which the muscle can develop rapidly diminishes; consequently, for both situations we must accept mean values provided it can be done without too great damage to accuracy.

4. Some motor events are so complicated and the result of so many individual factors that to compute mechanical events, factors of lesser importance must be eliminated. This is particularly the case in computing the mechanics of the gait. It is a license which admittedly detracts from the desirable accuracy of our computation. On the other hand it is useful and practical for purposes of drawing comparisons between normal and pathological situations.

The argument is advanced that all these concessions add up to a degree of inaccuracy which makes any mechanical analysis of locomotor events a futile effort. Against this stands the fact that the effect of mechanical forces on the human locomotion is so strong and dominant that even the aggregate inaccuracies do not vitiate the practical value of mathematical computations.

In comparing the relative efficiency of normal and pathological motor performances, another source of information comes from the science of physiochemistry. It consists in the determination by gasometric methods of the expenditure of energy and its relation to the output of visible motion, thereby establishing the efficiency quotient of the specific motor act. Any movement which requires a greater amount of energy for production of the same mechanical effect can be said to be performed with less efficiency and with less skill. The normal efficiency for certain movements such as walking, bicycling and so forth have been determined. For instance, normal walking has an efficiency index of 35%, which is a high rate for a combustion engine such as the human body represents. We also had occasion to compare efficiency indexes in certain pathological conditions, for example, paralysis, dislocation of the hip, etc., where the efficiency index was found considerably lowered. High efficiency can be established against clumsiness; economical against uneconomical technique of manual work; physical alertness can be compared with lassitude and sluggishness. Important as such observations are in industry, they are equally helpful to the physical trainer and still more essential to the surgeon engaged in the rehabilitation of locomotor function.

It is hardly necessary to adduce further evidence to show that the study of the mechanics of the human body is a practical even though a formidable undertaking. Its approach involves a number of fundamental principles.

The first of these is unbiased observation and truthful recording. In the last decades the methods of observation and records have made great advances: from simple photography to cinematography; from palpation and faradization to electromyography; from the kymograph to the oscillograph. We are now able to observe and measure motion as it occurs in the joints under normal and pathological conditions and to determine its effect on different parts of the body with much greater accuracy than before.

The second principle is that of analyzing the forces which produce motion. This makes it unavoidable to invade to some extent the field of general mechanics. Kinesiology differs from systematic anatomy in that it analyzes motion as it occurs under actual living conditions when carried out against some extrinsic force such as gravity or any other external resistance. We call