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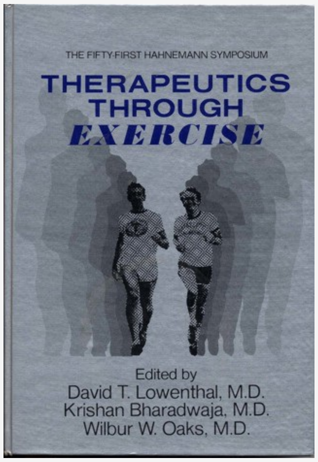
# Therapeutics Through Exercise

## Equipment Safety and Effectiveness

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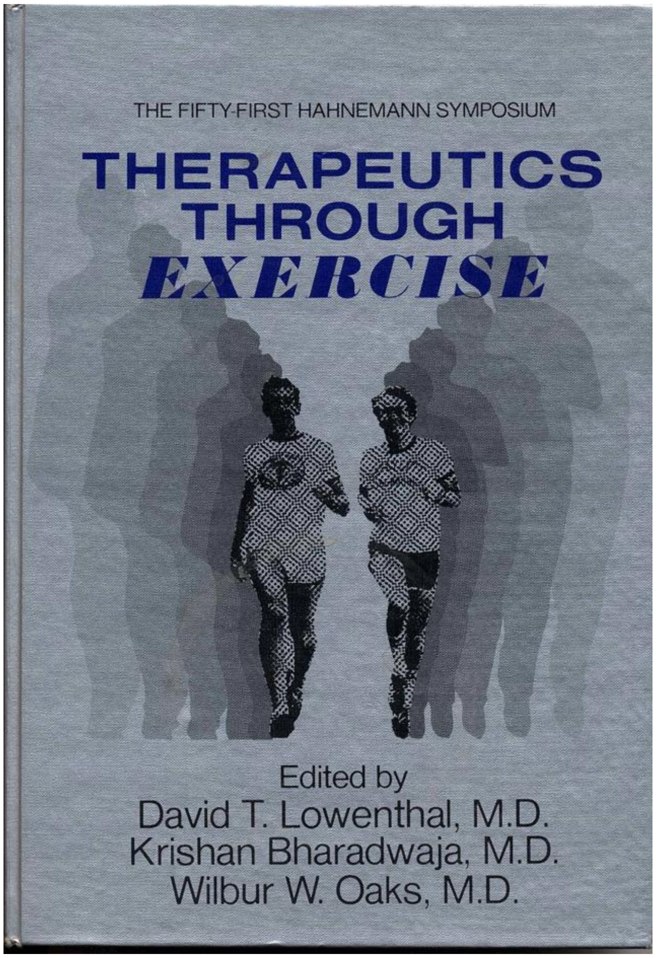


# Elementary Biomechanics

GIDEON B. ARIEL, PH.D.

How to explain movement and change is a problem that has attracted the attention of men since the time of the Anicent Greeks, and the ideas which the Greeks put forward dominated thinking for some 2000 years. The explanations adopted in the Middle Ages were largely based upon the writings of Aristotle, who lived from 384 to 322 B.C. Though some of Aristotle's views had been questioned earlier, it was not until the sixteenth and seventeenth centuries that the problems of movement came to be seen from the modern point of view. Many were involved in the preliminary discussions leading to this development, but the two most outstanding invididuals in what came to be a scientific revolution were Galileo and Sir Isaac Newton. It was the great change in the theory of movement, initiated by these men, which has since formed the basis for the modern scientific age. Alfonso Borelli, who studied under Galileo, theorized mathematically that bones serve as levers and that muscles function according to mathematical principles.

In perhaps the most powerful and original piece of scientific reasoning ever published, Sir Isaac Newton laid the foundation of modern dynamics.[1] Particularly important to the future of biomechanics was his formulation of the three laws of motion, which express the relationships between forces and their effects. These laws are as follows:

1. *Law of Inertia*–Every body continues in its state of rest, or in uniform motion in a straight line, unless it is changed by forces acting upon it.
2. *Law of Momentum*–A change in motion is proportional to the force causing the change, and the direction is in the same line as the impinging force.



3. *Law of Interaction*–For every action there is always an equal and opposite reaction.

Mechanics is that branch of the science of physics that encompasses the action of forces on material bodies. It deals with motion and includes the general principles and laws which make possible the applied science of biomechanics. Biomechanics is the study of the motion of living organisms including man. The field of mechanics may be divided into statics, which considers rigid bodies in a state of static equilibrium, and dynamics, which studies objects in motions. Dynamics may be further subdivided into kinematics, the geometry of motion, which includes displacement, velocity, and acceleration without regard for the forces acting on a body, and kinetics, which incorporates the concepts of mass, force, and energy as they affect motion.

For the coach, examination of a football place kicker presents a complex performance of interacting limbs and dynamic forces. While watching the kicker, the coach can ask a variety of questions:

1. What are the force-counterforce components between the upper and lower body segments of the kicker?
2. Was conservation of angular momentum utilized at the knee joint within the kicking limb?
3. Was an optimum position of the foot applied to the ball at the point of contact for force to be transferred from the kicking limb to the ball?
4. Was transformation of linear motion of the body and angular motion of the kicking limb adequate to effectively execute the skill?
5. What was the angle of projection and subsequent trajectory and flight pattern of the ball?

For the purpose of mechanical analysis, the individual performer—regardless of whether it is an athlete, a child at play, a doctor performing an operation, or a factory worker on the job—can be accurately represented mechanically as a series of interconnected rigid segments which comprise a complex link system. The primary complexity of such a link system is a function of the number of segments. Because any change in the state of rest or motion of a biomechanical system is governed by the action of external forces, it is important to identify these forces, their magnitudes, directions, and points of application. To facilitate this process, a free body diagram is constructed with all of the forces affecting the system. The system is thus analyzed taking into consideration the mass of each segment and its action, either acceleration or deceleration, through the sequence of the activity. Unfortunately, to process such a mathematical enormity by hand with paper and pencil would be prohibitively time-consuming. With the advent of computer technology and its accompanying peripherals, the millions of calculations could be more readily processed.

Kinematic and kinetic analysis of human motion has been expanded by the computer-digitizer complex so that analyses of total body motion can be accomplished through the use of slow motion cinematography, special tracing equipment for data acquisition, and the high-speed computer for computations.[2] Appropriate programming results in a segmental breakdown of information of the whole motion including the total body center of gravity, segment velocities and accelerations, horizontal, vertical, and resultant forces, moments of force, and the timing between the body segments. This analysis provides a quantitative measure of the motion and allows for perfection and optimization of human performance at a speed which can reasonably be incorporated into any athletic training program or rehabilitative regimen. An additional advantage is that reduction of the motion system to a mechanical problem permits an objective, quantitative assessment of performance, replacing the uncertainty of trial and error, eliminating doubt, and providing a realistic opportunity for improved performance.



The analysis involves the following steps:

1. Obtaining cinematographic data.
2. Digitizing the data.
3. Measuring and utilizing anatomical data.
4. Utilizing computer software for the manipulations of the equations of motions.
5. Interpreting the results.

Slow motion cinematography is used to record the desired motions. This technique permits an undetected recording of an individual's performance under actual conditions—an advantage over accelerometers or force transducers with their accompanying wires. Film speed must, of course, be fast enough so that actions are not blurred, and therefore most human activity is recorded at speeds of 64 to 200 frames per second.[3]

The second step in data processing involves a composite tracing of the joint centers of the body. This is accomplished by locating the joint centers with a sonic pen-microphone arrangement so that x and y coordinates are represented within the computer memory for each joint and each position for the entire movement sequence.

Calculation of forces and moments of force requires knowledge of the mass of each segment as well as its center of gravity. These parameters are available from NASA research, and tables of body segment percentages of total body weight, specific gravity, and segment lengths as percentages of total height may be used when data is not available on the specific performer.[4,5] There are, however, various methods for calculation of the weight, volume, and the center of mass of segments of the body when the subject is available. In order to calculate the forces, it is necessary to know the radii of gyration which may be calculated from Dempster's data on moments of inertia.[6]

After the joint centers are acquired and stored in the computer, the segment lengths and angles can be ascertained while calculations of the segment masses, centers of gravity, and radii of gyration are obtained from the anatomical data. Knowledge of the film speed and the displacement of the joint centers enables calculation of the velocities of the body segments, and from the velocities it is then possible to calculate segment accelerations. Segment masses are utilized in the calculation of forces and moments of force. Appropriate computer software yields a segmental breakdown of information of the whole motion, including; the total body center of gravity; segment velocities and accelerations; horizontal, vertical, and resultant forces; angle of the resultant force application; moments of force, which indicate the magnitude of the muscle action at each joint; the vertical and horizontal forces at the ground contact points; the timing or coordination of motion between the body segments; and the differences due to discrepancies in body builds.[2] A quantitative measure of the motion results from the combination of the moments of force, the interrelated patterns of the body segments, and the task performed. Following these calculations, it is possible to alter various positions of the body segments in order to determine the effects on the motion that such hypothetical changes would cause or for optimization of the activity.

An example of this optimization procedure can be illustrated using patterns of the velocity curves for each segment in a golf swing.[7] A typical professional golfer will produce a sequential arrangement of the timing of the peak velocity for each segment of the heavier segments, such as the thighs and trunk, slowing down so that they "stop" at a point immediately before impact occurs. The arms and club segments, on the other hand, reach peak velocity prior to impact with the club velocity being the greatest at or near impact. This type of coordination of velocities and their resultant accelerations is typical of most athletic events which are ballistic in nature. If a less skilled golfer is examined, his patterns may not conform to such a sequential arrangement, and with the computer software, the performance of this individual could be altered to determine the optimized results.

Research and opportunity continue to reveal new applications for biomechanical analysis of human performance. The application of the scientific tools of mechanics and the speed of computer technology offer refreshing opportunities for quantification of motion and the removal of trial and error.

## REFERENCES

1. Sears F, Zemansky MW: *University Physics*, ed 4. Reading, Mass, Addison-Wesley, Inc, 1973
2. Ariel GB: Computerized Biomechanical Analysis of Human Performance. in: *Mechanics and Sport*. The American Society of Mechanical Engineers, 1973, Vol 4, p 301
3. Mascelli JV, Miller A: *American Cinematographer Manual*. Hollywood, American Society of Cinematographers Holding Corp, 1966
4. Clauser CE, McConville JT, Young, JW: *Weight, Volume, and Center of Mass of Segments of the Human Body*. Wright Air Development Center, AMRL-TR-69-70, Ohio, Wright-Patterson Air Force Base, 1969
5. Krogman WM, Johnston FE: *Human Mechanics: Four Monographs Abridge*, AMRL Technical Documentary Report No. AMRL-TDR-63-123, 1963
6. Dempster WT: *Space Requirements of the Seated Operator*. Wright Air Development Center TR-55-159, Ohio, Wright-Patterson Air Force Base, 1955
7. Ariel GB: Comparative Biomechanical Analyses of the Golf Swings of President Gerald R. Ford and Jack Nicklaus. Technical Report Conducted for *Golf Magazine* 20(10):56, 1978

# Equipment Safety and Effectiveness

GIDEON B. ARIEL, PH.D.

Biomechanics is the study of the structure and function of biological systems by means of the methods of mechanics. Mechanics deals with the description of motion as well as the forces that act on objects to cause motion. Therefore, mechanics is divided into two sub disciplines: kinematics and kinetics. Kinematics deals with the description of motion and kinetics deals with forces.

The three factors underlying all human movement are displacement, duration of movement, and forces. All of these are equally important in human performance. In all motor skills, muscles provide the forces to move the body through the activity, while the displacement of the body parts and their speeds are important in the coordination of the activity. Direction and speed are directly related to the forces produced.

In order to measure human movement, there is a need for either a measuring device attached to the body or the utilization of cinematographical techniques. An unfortunate limitation to the attachment of transducers to the human body is the chance that the body movement may be impaired. In addition, a transducer necessitates wires or telemetry electronics which are usually cumbersome or lacking in accuracy. It is possible to record motion on film by means of film recording techniques, and then reduce the data into a coordinate system for further calculation of displacement, velocity, and acceleration of the body segments by means of digitizers. In the past, this procedure was very laborious and extensive. Recently, however, the biomechanics of human motion has been aided by computer technology, which has resulted in the feasibility of rapid calculations of large quantities of data. The computer–digitizer complex has reduced the long, tedious hours of tracing and hand calculations to a matter of minutes, and thus complex whole body motion analysis can be easily obtained.[1, 2]

The laws of physics apply to any system in motion regardless of whether the system is a living organism or a machine. The human body may be likened to a machine made up of mechanical members: the joints serve as fulcrums and the contracting skeletal muscles exert forces on the segments. The segments of the human body form a link system consisting of segments such as the foot, shank, thigh, trunk, shoulders, upper-arm, forearm, and hand. In order to perform a biomechanical analysis of the human body, the following steps are necessary: obtaining cinematographic data by utilizing high speed cameras; digitizing the data; measuring and utilizing anatomical data; utilizing the computer programs for kinematic and kinetic measurements; and interpretating the results.[3, 4]

The purpose of the present paper is not to derive the equations of motion since these equations can be found in any physics textbook, but to illustrate the significant contribution of biomechanics to optimizing human performance. In appreciation of the genius of humans, Ben Franklin wrote: "Man is a tool–making animal." Tools are implements that assist us in our life. A shovel facilitates snow removal. A shoe protects the foot. A golf club drives a ball towards the green. Stairs provide an economical way to overcome gravity. In a modern technological society, indeed in any but the most primitive societies, we are tied to an almost infinite variety of simple and complicated machines.

Human beings seem to have become so infatuated with their ability to invent things, however, that they have concentrated almost exclusively upon improving the efficiency and safety, adding to the durability, reducing the cost, or enhancing the aesthetic appeal of the device in question. Badly neglected has been the key tool, the most versatile instrument of all, the human body, with its own marvelously sophisticated capacity to grip, lift, push, carry, and manipulate. It can perform wonders by itself and is even more effective when connected with one of its own innovations, the tool.

Unfortunately, in spite of their inventiveness, human beings often studiously ignore their own reality as a set of arms and a torso at the end of the working shovel. The shovel alone moves no snow. Inside the shoe is a foot that is attached to the body. The shoe does not become a working tool until the foot employs it. The dynamic properties of the golf club undergo a radical change when it leaves the bag and becomes a tool swung by the arms of a particular individual.

But other forces have continued to compose the tunes played by designers and producers of tools. Vanity decrees that women wear high heels, a threat to both their immediate and long-term health.[5] Tradition dictates the dimensions of stairs, one of the greatest hazards in buildings. Ignorance guides the design of furniture so that even a Bauhaus giant such as Mies Van Der Rohe creates an aesthetically breathtaking chair that is a sure contributor to the potential for backache and varicosities. Common household books of matches become tiny incendiary bombs because of a failure to consider the dynamics of striking a match. Automobiles continue to be an uneasy marriage of economics and safety without any true appreciation for the human factor.

The drive to defeat physical decay and postpone death dances to the beat of



hucksters pushing exercise programs and equipment that may not suit the individual. The current mania is jogging. Because too little attention is being paid to what is actually a foot in jogging, the activity may prove to be another DDT—the miracle pesticide—until 20 years later we discover that along with the bugs, it has been killing us. Immediate gains can have far off costs. Only in the most intricate technological systems, those that are enormously expensive and life threatening, such as space missions or highly sophisticated weapons systems, is there serious attention paid by the builders of tools and machinery to how the human body moves, applies force or pressure, reacts to resistance.

A full cure for the wasteful assault upon nature's most noble invention, the human body, is the application of the science of biomechanics. This is the discipline that concerns itself with environmental effects of forces, velocities, and accelerations upon living organisms and, most particularly, homo sapiens. Biomechanics covers the mechanical actions of humans, whether they are simply using their own bodies or whether they are relating to other objects, devices, or persons.

Biomechanics also includes biocybernetics—the systems of control and communication within a human.[6] Simple biomechanics deals only with the calculation of forces, masses, acceleration, velocity, and movement of segments of the body. But something must coordinate all of the body's forces if one is to achieve an optimum performance, the best that he or she can accomplish under the circumstances, whether it is in an Olympic event or in shoveling out a snow-filled driveway.

Biomechanics in its widest sense seeks to find the principles that organize the interaction of the nervous system with the musculature. Coaches, trainers, physicians, physiologists, biochemists who ignore the control and communication apparatus, indeed anyone who doesn't include biocybernetics in the explanation of human movement, limits the discussion to vague superficialities.

The spiritual father of biomechanics is Leonardo da Vinci, who wrote: "Mechanical science is the noblest and above all others the most useful, seeing that by means of it all animated bodies which have movement perform all their actions." Others in the century or so after Leonardo echoed his thinking. An early 18th Century Italian Professor of Anatomy, Giorgio Baglivi, described the entire human body as a mechanical system: ". . . a complex of chemico–mechanical motions, depending upon such principles as are purely mathematical. For whoever takes an attentive view of its fabric, he'll really meet with shears in the jaw–bones and teeth . . . hydraulic tubes in the veins, arteries and other vessels . . . a pair of bellows in the lungs, the power of a lever in the muscles, pulleys in the corners of the eyes. . . ."

Apart from space missions, however, biomechanics appears to have made inroads into the consciousness of only one modern form of human endeavor, sports. Unfortunately, even there the vision of biomechanics seems to be clouded, suggesting that the use of the science's language is less a concern for integrating the human more efficiently into the relationship with equipment than it is to use the imprimatur of biomechanics as one more hype for selling.

For example, ads for a brand of tennis shoes brag, "extra deep, extra soft padding and cushioning, over 200 individual pads to grip the playing surface like the claws of a cat for instant starts and stops and lightning moves." There is not a shred of scientific evidence to show that piles of padding in a shoe absorb the shock to the body when a human runs during a tennis game. Tests show that the "200 individual pads" do not provide any more traction than any other contours of a sole bottom. Furthermore, humans do not move the way cats do. The hyerboles of advertising have become so accepted that one is tempted to ignore the outrageous claims, but if biomechanics is going to have any effect it must begin to shout about the emperor's nudity.

"A larger sweet spot," claims another tennis ad, this one by the manufacturer of a racket with an oversized face. In scientific terms, the sweet spot is the center of percussion. That is the point where any effective application of force will be completely counteracted by the mass acting upon that point. That means that for a rigid rod, such as a tennis racket or a baseball bat, the impulse or force transmitted through the racket or bat at the point of contact would not be felt at the point of the rod's suspension, which in the case of a racket or bat would be the hand or hands. But the makers of the racket determined the sweet spot or center of percussion on the basis of the instrument alone. They omitted the key element—the player. Unfortunately, in spite of the brochures issued by manufacturers, tennis also follows the laws of physics. In a player's hand the racket is no longer an independent rod with is suspension point located at the end of the handle. It is instead a piece of a lever that stretches from the shoulder through the hand to the tip of the racket. The true point of suspension is the shoulder joint. When biomechanial analysis was conducted and the data analyzed utilizing computer technology, the racket as part of a lever that included the entire arm, the center of percussion, or sweet spot, in the buzz word of the industry, was in the player's wrist. It would indeed be a triumph if a racket could be designed so that the center of percusion lay in the racket strings because that would go a long way towards the elimination of tennis elbow. If one consistently struck the ball on a center of percussion within the racket strings, no forces would be transmitted up the shaft of the racket to injure tendons, ligaments, or muscles.

Currently, jogging is another sports growth industry in the United States. The number of runners is surpassed only by the vast quantities of products for joggers and the claims made for these items. In particular, manufacturers, eager to cash in on the popularity of jogging, have created zippy-looking shoes decorated with flashy colors and stripes. All are allegedly endowed with special constructions that make the jogging go better. There is little actual biomechanical science behind any of these shoes. Jogging merits much more attention from a biomechanical viewpoint than it currently receives. It apparently does benefit the cardiovascular system under some circumstances. But what profits a man or woman with a healthy heart if at age 40 or 50 they are crippled by ankle and knee pains, shin splints, degeneration of disks and cartilege, and chair bound by traumatic arthritis? They may indeed be the biomechanical price for jogging in the modern urban environment.

Walk into any quality sporting goods store and look at the golf clubs. For sale to all comers are sticks bearing the autographs of Jack Nicklaus, Johnny Miller, Jerry Pate, or whoever happens to have scored well on the pro golf tour during the year. Obviously, Jack Nicklaus's golf clubs serve his game well. He has had them built to fit his specifications, the dynamics of his swing, and his particular body interacting with these special clubs. The weekend hacker who lays out several hundred dollars for a set of clubs designed by and for Jack Nicklaus ignores a basic component in his



golf game—himself and his own biomechanical functioning. He may well fall into the percentile of the population that does not match the Niclaus somatype.

To summerize, the age of biomechanics which is dawning now offers much larger and more positive opportunities than just a kind of consumer's guide to sports and recreation equipment and techniques. Biomechanics can literally improve life from cradle to grave. If properly applied, biomechanics can aid newborns to explore their environment and develop their muscles better. The young can be taught how to get off on the right foot when they begin to walk. Much of what surfaces as a health problem with middle age begins during the early years of life. At the other end of the spectrum, biomechanics possesses the means to supply programs that will preserve the strength and the flexibility of aging bodies ravaged by time or even illness. Years of life may be added or, at the very least, older people will be able to enjoy more active, more comfortable lives.

## REFERENCES

1. Ariel GB: Computer Analysis of Track Biomechanics. *Track Technique* 50:1597, 1972
2. Ariel GB: Computerized Biomechanical Analysis of Track and Field Atheltics Utilized by the Olympic Training Camp for Throwing Events. *Track and Field Quarterly Review* 72:99, 1972
3. Ariel GB: Computerized Biomechanical Analysis of Human Performance. *Mechanics and Sport,* The American Society of Mechanical Engineers 4:301, 1973
4. Ariel GB: Method for Biomechanical Analysis of Human Performance. *Res Quart* 45:72, 1974
5. Ariel GB: Computerized Biomechanical Analysis of Athletic Shoe. *V. International Congress of Biomechanics Abstracts,* Jyvaskyla, Finland, 1975
6. Arbib, MA: *The Metaphorical Brain.* New York, Wiley-Interscience, 1972