HISTORICAL OVERVIEW OF BIOMECHANICS

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This treatise is presented primarily to motivate the young investigators. They are technically trained better than most of us here. However, I believe they need more insights and employment of common sense approaches before we can accept them as great biomechanists. If all they have are technical skills, they are: to paraphrase a Bible quotation (Mark 8:36) "Whosoever knows all things technical but has not wisdom is without substance," or for the aspiring, "For many are called, but few are chosen." (Matt. 23:14)

Perhaps it would be wise to first define biomechanics. Winter defines the term biomechanics of human movement "as the interdiscipline which describes, analyzes, and assesses human movement." (18) He further stated that "it is an emerging discipline blending aspects of psychology, motor learning and exercise physiology as well as Biomechanics." (18) Most of us know the foundation of the field is the knowledge from anatomy, physics, mathematics, physiology, and perhaps chemistry. Therein lies some of the difficulty in preparing for a field so diverse in its requirements that it is impossible to be knowledgeable in all these areas. Most young biomechanists have taken extensive work in mathematics, computer science, and some courses in physics and anatomy. Some have a minor in physiology.

Who are the best trained of the people in the field? It depends on what the job requirements are for a specific situation. There is a need to have some background in all these areas. Most of the older biomechanists were originally trained in other fields. (For example: Physiology) Some taught kinesiology but had a coaching background and wanted more application thus became interested in revising the course content or at least changing the emphasis. Most might be said to be self-trained in that sense.

PEOPLE AND THEIR CONTRIBUTIONS

There are many people who have contributed to the understanding of biomechanics in sports. There will be no attempt to have this treatise all inclusive. Some effort will be made to place these individuals in chronological order where feasible and pertinent. (17, 13, 1)

Aristotle - He was the first to analyze and describe some of the complex movements such as walking and running.

Archimedes - He determined hydrostatic principles governing floating bodies.

Leonardo da Vinci - He was interested in the structure of the human body and how it functions in performance of gait and other human movements.

Galileo Galilei - He stated that "Nature is written in mathematical symbols." He is credited with defining the action of falling bodies.

Alfonso Borelli - He related muscular movement to mechanical principles.

Sir Isaac Newton - He laid the foundation of modern dynamics with his three laws of "at" rest and movement.

Eadweard Muybridge - He developed cinematographic serial pictures in order to study animals and humans.

Etienne Jules Marey - He used graphic and photographic procedures to describe movement.

Christain Wilhelm Braune and Otto Fischer - They laid the foundation for scientific studies of human beings in action with their experimental method of determining the center of gravity of the human being.

Jules Amar - He brought together in one document all he could find on the physical (mechanical) and physiological elements involved in industrial work.

You might have selected other names to present.

Figure 1.
Man in action carrying a device to record pressure vs. ground and vertical movement of the head. (Marey, E.J., La Machine Animal, Felix Alcan, Paris, 1886)

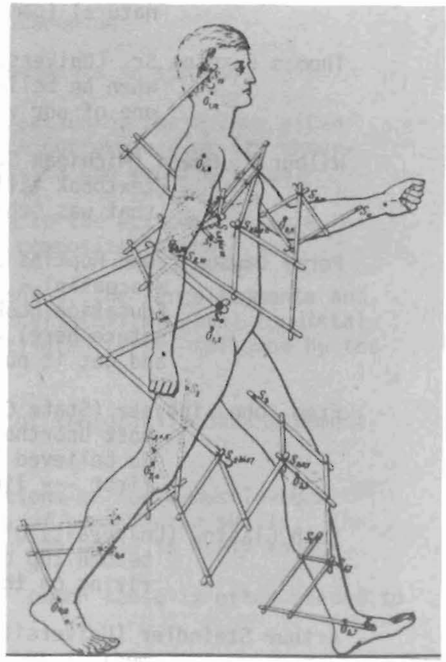

Figure 2.
Model of the human by which the body's centers of gravity may be determined. (From Fischer, O Der Gang des Menschen II. Teil, Teubner, Leipzig Tag I.)

It is known that early man was interested in movement. The Egyptians (5000 B.C.) had artists paint humans in action on the walls of the tombs of kings. During the Mochico Culture in Peru (1 A.D.) vase paintings showed warriors in action. Later Greeks had similar paintings. The early Chinese used vase paintings to depict human movement.

THOSE IN THE IMMEDIATE PAST

Those of the immediate past such as: N. Posse, W. Skarstrom, Wilbur Bowen, and W. O. Fenn must be mentioned as those who helped in the development of the foundation on which American biomechanics was built. Please let me highlight nine early Americans not necessarily mentioned previously. (8)

C. H. McCloy (University of Iowa) - He was a dedicated biomechanist who saw value in analyzing performers in a natural (game) situation.

Thomas Cureton Sr. (University of Illinois) - "Spoke his mind" when he believed in something strongly. He was one of our very first biomechanists.

Wilbur P. Bowen (Michigan State Normal College) - He wrote a textbook titled Applied Anatomy and Kinesiology that was "the" textbook for over twenty years.

Percy Dawson (John Hopkins University and the University of Wisconsin) - He wrote the Physiology of Physical Education book (there is much of a biomechanical nature here) where he dared to write phonetically and got it published.

Fred John Lipovetz (State College, LaCrosse, Wisconsin) - The most unorthodox of all deviates in biomechanics. He believed he should do everything as subject first --- like drowning (almost).

Ruth Glassow (University of Wisconsin) - She has had more students become top biomechanists than any person yet arriving on the scene.

Arthur Steindler (University of Iowa) - He tied together the medical and human movement fields.

Marion Broer (University of Washington) - She made a very successful attempt to make kinesiology (biomechanics) a practical field.

What would C. H. McCloy or W. O. Fenn have accomplished with today's tools? Probably more than any of us present. Observe an idea on digitizing equipment I had before digitizing was so easy (Figure 3,4,5).

SOME UNDERLYING PRINCIPLES

Knowledge of some underlying principles is necessary in order for the budding biomechanist to understand sports movement. Permit me to present a few for your careful scrutiny.

1. There is a hierarchy to movement - they are all linked together.

   Swimming, crawling, climbing, walking, running, jumping, throwing, and complex movements involving all or part of these movements.

2. Must thoroughly understand walking in order to understand running and other movements, even throwing.

3. Physical laws govern almost all movements in sports.

4. Modifications of or specific application of these laws often need to be made in order to enhance performance or its understanding. Each sport or skill has its own peculiarities.

5. Each movement has a certain rhythm to the action. This is coupled with the individual's own composite rhythm.

6. Most actions begin with the movement of the large segments and progress to the smaller ones. We call this proximal to distal with the larger segments being activated first, followed by the lighter segments.

7. Most performers are often unaware of the details of a movement and probably should not be aware.

8. Motor patterns are unique combinations of nerve-muscle-bone actions. They are the foundations of human motor skills. They need not be learned if exposure to the child is early enough.

9. Computer data does not tell all. Common sense is often needed to discover errors in the print outs.

10. Often motions begin at an external position and move internally then externally. It might be said there is a plane of movement from outside the mid-line of the body toward the mid-line and then away from the mid-line in a frontal plane.

11. A performer may perform well in one sport and poorly in another. The components are seldom the same from sport to sport.

12. Don't always believe what you read. Even the best scientists can be wrong. Certainly newspaper reports can carry misleading comments. Some information is wrong that is published in our most prestigious journals. Challenge carefully.

ISSUES AND SOME SOLUTIONS

1. Better trained individuals should be in charge of many of the kinesiology/biomechanics programs in the colleges and universities. Conversely, the programs should be rigorous enough to challenge the most talented and scholarly.

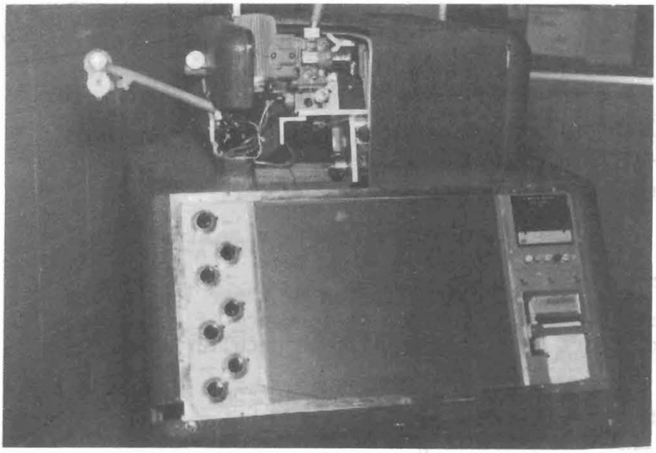

Figure 3

Projection and print-out system which includes X and Y coordinates, angle of projection and velocity.

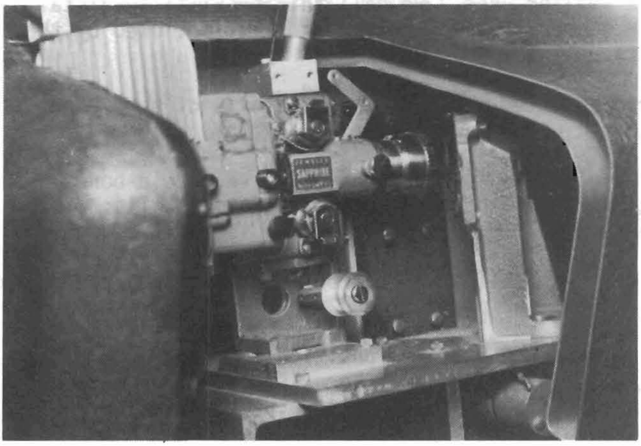

Figure 4

Inside mechanisms of early digitizing system.

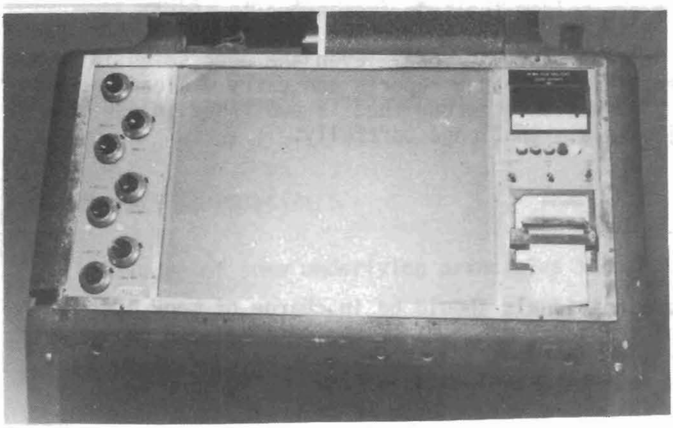

Figure 5

Print-out system of an early digitizing system.

2. Panning action is being reported on here at this conference as a viable procedure when using only one camera. This has been a problem for many years. Here's hoping it will be solved as anticipated.

3. The lack of the proper number of subjects considered statistically sound is not quite the problem it was some years ago. However, being able to randomly select and secure the best representative types is still with us.

4. Basing body segment data on information taken from live subjects (not cadavers) is still a problem. The following have been tried:

   a. Gamma-ray spectroscopy not too successfully.
   b. High energy x-ray beams are hazardous to health of human subjects.
   c. Holography for tri-dimensional situations is still possible and being done to some extent but is too expensive for use in the average biomechanics laboratory.

   There are others that have been tried but this problem is still here.

5. There is a bit of isolationism being practiced among the sport sciences. Experts from various areas don't get together often enough to really exchange ideas. At the recent sport medicine conference held in Minneapolis (1982) the various interest groups for the most part met separately.

6. The laboratory has to be moved at times to the sports fields in certain situations in order to secure data under game-like conditions. Data secured otherwise may not be valid.

7. The coach wants film data (and other data) by the next day after the filming has occurred. Overnight processing is essential. Digitizing and analysis can be done more leisurely but not later than one month after the filming has taken place.

8. The terms research and applied research must be interrelated. Perhaps just the term research should be used without the discrimination that now occurs.

   Some means of communicating how the use of biomechanical principles have helped improve performance is needed. Have we proof of biomechanics being used by performers and coaches? Plagenhoef last year here in San Diego at the SPIE meetings questioned if there was irrefutable evidence on this point. James Hay (12) has cited James Counsilman and Robert Schliefhauf as accomplishing this task (in swimming) more than anyone so far in his opinion. I am sure there are many isolated cases where biomechanists have had their findings applied. Let's see that this problem is erased.

9. Biomechanics will be vital to the following fields:

   a. Developmental aspects of the growth of children.
   b. Rehabilitation of exceptional children, the handicapped and the sports injured.

10. There should be a biomechanics expert connected with most large industries to help solve their movement problems.

11. Biomechanists should be available to be consultants to national sports groups, safety environmental programs, and school and university teams and in most movement situations regardless of the environment.

12. Colleagues in the universities from other disciplines should be encouraged to seek advice if desired from biomechanists on all movement problems.

13. Have you reviewed related information from other fields? The new field of kinanthropometry is very intriguing. It has been described thus, "We now view kinanthropometry as the application of measurement to the study of human size, shape, proportion, composition, maturation, and gross function. Its purpose is to help us to understand human movement in the context of growth, exercise, performance, and nutrition. We see its essentially human-enobling purpose being achieved through applications in medicine, education, and government." (16) It is an emerging area of study cutting across several disciplines in its interest. It involves the whole spectrum from verifiable truth to subjective judgment, thus in this sense, it is not an exact science. However, biomechanists will gain many insights from this field by studying their deliberations.

14. There is not a complete understanding of all terms involving tools, equipment and techniques. It is recommended that there should be an atlas of biomechanical terms developed so there is clear understanding what each term means throughout the world.

USE OF MEASUREMENT TECHNIQUES

A few years back it was reported (7) that biomechanics was just at the measurement level. It has progressed beyond that point now to where most any statistical technique that is applicable can be used by the biomechanist. This situation has been brought about by the available computer packages and ability of biomechanists to use these packages and also to write their own programs. Some of these techniques and procedures now in use will be presented. They are: Statistical techniques, smoothing techniques, computer languages and modeling.

Statistical Techniques: (Does not include various mathematical procedures such as cubic-spline functions etc.)

The following are some of the statistical procedures now being used by graduate students and researchers.

Descriptive Statistics

Central Tendency	Variability
Mean	Standard Deviation
Median	Semi-interquartile Range
Mode	Range

Correlation

Zero Order (Pearson product moment)
Partial
Semi-partial (part)
Multiple

Inferential

T-test
Analysis of Variance
Chi-square

Multivariate

Factor Analysis
Canonical Analysis
Multivariate Analysis of Variance
Descriminant Analysis

Smoothing Techniques:

Best Fit	Polynomial Techniques
Graph-Numerical	Spline Functions
Finite Differences	Fourier Harmonic Analysis
Least Squares	Digital Filtering

These techniques must be used in a common sense setting. You can smooth out all resemblance to the real movement.

Computer Languages:

There are over one-hundred different computer programming languages. However, researchers are finding that the availability of a growing number of application programming packages like SPSS and IMSL are satisfactory. Consequently, the necessity of writing new programs is diminishing. The most commonly used languages are:

Fortran	(IBM developed this language in the mid-1950's as a general purpose language.)
Basic	(This is a language like Fortran but it is stripped down and simplified. It was developed at Dartmouth University and is very popular because casual users may easily make use of it.)
Pascal	(This is a relatively new general purpose structured programming language.)
Cobol	(This is the world's most popular language. It is business oriented.)
Forth	(This language is used in micro-processors. It is specifically for small machines and will be popular in the future.)
Lisp	(This is a language used in list processing. Artificial intelligence is used extensively by computer people for list processing.)
Simscript	(This language is used to specify processes for simulation studies.)
SPSS	(This is not a language but is a collection of statistical programs written in Fortran. BMD and SAS are very similar to SPSS.)
IMSL	(This is a collection of Fortran programs. It is a mathematical package. The program performs popular mathematical calculations.)
Assembly Language	(This machine dependent language is designed around the architecture of a specific machine.)

Modeling:

A model is a representation of something that is real and it is a tool to be used in the analysis of/or the design of some existing system or action. (3) It is an attempt to simplify and make more accurate the procedure used in the analyzation of complex movements. It becomes easier and more efficient to analyze an action if the modeling results in the "soul" of accuracy. However several that I have seen in our field are only approximations and not always useable in simulating a physical course of events and in determining how changing one or more aspects of a movement may affect other aspects of the movement.

Master Teachers

We need master teachers as well as researchers in biomechanics. Many of the present young outstanding biomechanists have indicated to me they want contact with only a few students and they want them to be outstanding. Some of these leaders of the future have also said they much prefer to be in a laboratory setting all or most of the time. Fine, but who will do the teaching? Probably the least qualified and maybe the poorest teachers will be the result.

Benjamin S. Bloom in his article on The Master Teachers (4) stated that he and his colleagues identified six different fields and twenty-five persons born in the United States who had reached a high level of accomplishment before the age of thirty-five and could be classified as world class.

They began their study by centering their attention on concert pianists and olympic swimmers. Who were their teachers, and what qualities did they possess? Usually they had three teachers during their careers. The first teacher was often not highly talented but very personable and gave forth a lot of encouragement. The second teacher selected only the most promising students. The third and finishing teacher was selected with infinite care and much discussion. Also, the final teacher did the final selection. This teacher would take only those who were the most outstanding, well disciplined and totally committed to the field. These teachers had a reputation which they did not want marred by failures; they possessed egos equal to or greater than their students.

What did the swimmer teachers look for in their prospects? They were:

1. Feeling for the water and an efficient stroke.
2. Competitiveness by being dedicated to be the best.
3. Flexibility of body parts.
4. A good contribution of the above traits.
5. Strong desire to reach the highest level.

Bloom stated that it would not be possible for the final teachers to be either the first or the second because they demand too much and lack patience to develop raw talent.

Aside, the late Geoffry Dyson (10), outstanding English track and field applied biomechanist, told the presenter in personal communication on his last trip to the United States before his death that a developer of track and field talent must be one who has "tasted" the depths of defeat as well as the triumphs of victory. He thought that undefeated performers often made poor teachers and coaches.

Finally, Bloom's (4) comments that have been presented are worth considering in the development of talented biomechanists. The combination of "great" teacher and "great" researcher could be realized but not without great effort and usually at the highest level probably impossible. A story about a renowned American physicist who had helped develop the atomic and hydrogen bomb, is told here. He was assigned to teach a beginning physics class. I was told that the first few days of his class sessions there were not enough chairs or seats in the auditorium to accomodate all the students so they lined up against the walls on all four sides. As the weeks progressed fewer and fewer students remained in the class. Why? Some had enrolled out of curiosity, it is surmised. Others most likely were not qualified or oriented toward science? Maybe the renowned physicist just was not oriented toward teaching beginners. Who knows the answer except to say that not every great researcher is a great teacher.

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