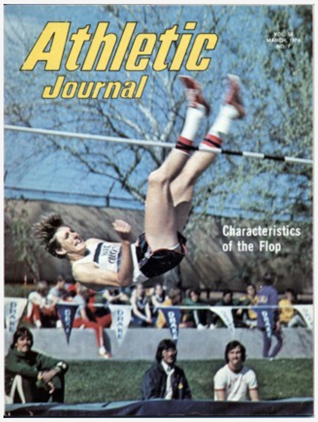
Computerized Biomechanical Analysis

Computerized Biomechanical Analysis of Human Performance



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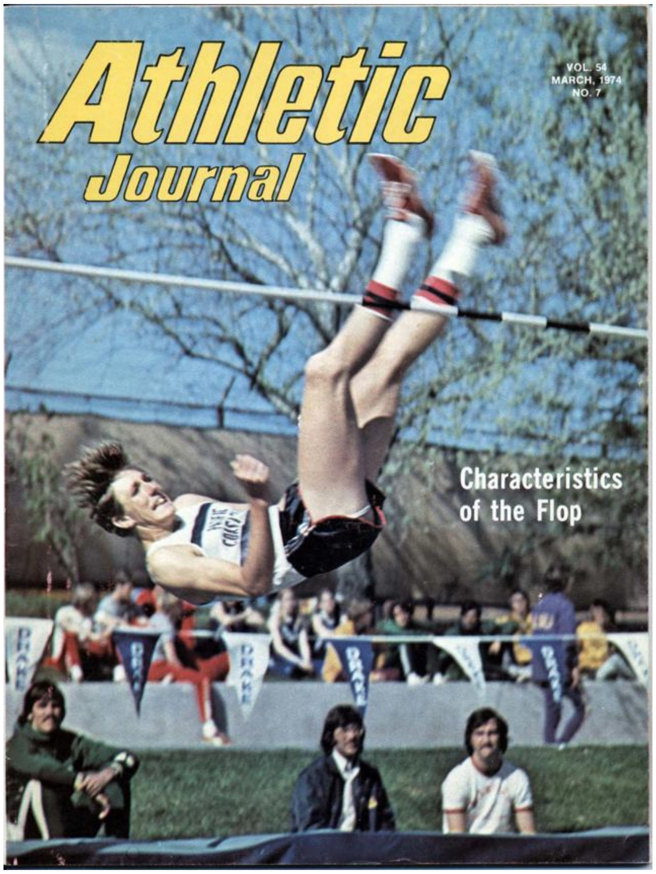

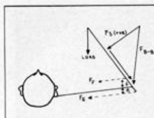

F_F = Flexor Contractile Force
F_E = Extensor Contractile Force
F_{B-B} = Bone-on-Bone Force
F_A = Bone-on-Bone Shearing Component of Force
F_C = Bone-on-Bone Compression Component of Force
f = Flexor Force Arm (4.4 cm)
e = Extensor Force Arm (1.8 cm)

Computerized Biomechanical Analysis of Human Performance

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FOR assistance in the research of this study, I am indebted to Chuck Coker and Harold Zinkin of the Universal Fitness Research Department.

The history of man is filled with evidence of his efforts to develop new techniques and equipment which satisfactorily serve his purposes and to control more adequately the environment within which he lives and works. Over the years much of what physical educators, coaches, and physical trainers knew about how man moved and performed was the result of visual observation and subject to biases and opinions. The movements of man, especially in sport and physical training, are much more complicated than can be accurately analyzed by the human eye.

A few typical questions might be posed which will illustrate what is meant by *taking human factor considerations into account* during the analysis of human performance. Such questions could include the following: Which muscles are involved when executing a block in football? Which muscles need special strength development for each individual track and field event? To what extent does the bench press exercise develop the elbow extensors? Which muscular exercise would best suit the development of the knee extensors (quadriceps) with minimal shearing force at the joint? How much resistance should be varied throughout a range of exercise motion to obtain the most efficient exercise routine?

The solutions to these and many other kinds of questions should be based on the availability of pertinent information about human capabilities and limitations as well as physiological, biological, and biomechanical factors. The development of a body of information and principles that would be applicable to these and other problems is primarily dependent upon research. At present there is fairly substantial information available about some areas of human performance such as physiology of exercise. There is at least partial information about certain biomechanical principles. However, in some areas the information available is quite limited, for example, in the design of exercise equipment for muscular development.

The purpose of this article is to introduce a new method for analyzing human performance. This biomechanical technique enables optimum development of muscular strength and endurance for a particular sport or for every day fitness.

The term biomechanics refers to a systematic application of the laws of mechanics and biological concepts — anatomical and physiological — to problems of human motion in a given situation in order to help man move more effectively within whatever environment he must function. It is both a quantitative and qualitative approach to the study of forces both internal such as muscular forces, and external such as resistance forces in weight training. Although subject to the same laws of motion as inanimate objects, man has the capacity to change either the way he moves or the tools and equipment with which he works so he can adapt to different environments. In sport, the athlete must contend with problems in his own special environment. Forces including muscular and frictional as well as external forces (e.g., the shot put, discus or the weight-lifting bar), affect the way he must move. Exercise equipment for the athlete must be designed based on data obtained from a method which includes all of these forces. These problems have been under investigation for a long time; however, only since the development of biomechanics and the invention of the computer, have researchers been able not only to view, but also to do a more thorough kinematic and kinetic analysis of human performance.

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The Scientific Principles
Underlying the Analytic Technique

When performing any exercise with the *Universal Exercise Machine*, the segments of the human body which are used form a link system. For example, in the bench press the link system consists of the trunk, the upper arm, and the forearm with the weight in the hands. Diagram 1 shows this link system. The laws of physics apply to any link system in motion regardless whether the system is a human or a machine. The different segments of this link system, when in motion such as in the bench press exercise, include muscular forces which act on each body part, and in addition to the muscular forces, there are inertial forces which are the forces produced by the motion itself.

If the human body had only one segment, then designing an exercise machine would be very easy since only the inertial and muscular forces on that

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segment would act upon it. However, the human body, when performing physical exercise, has more than one segment in use even if some of the segments are fixed. For example, when a link system consists of two segments such as the upper arm and the forearm, then gravity, centrifugal, and tangential forces act upon each segment with an additional three forces resulting from the influence of the first segment upon the second. In some resistance exercises, as many as nine segments are considered in the analysis. Universal laws affect a link system so that each segment in motion has the previously mentioned three forces and additional forces due to the influence of segments on each other. In a link system of seven segments such as in the shot put throw, a total of 84 forces are involved in each sequence of the throw. An exercise machine developed from this type of information can maximize the training effect.

Analysis Procedure

The kinetic analysis involves the following steps:

1. Obtaining cinematographic data

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the moments of force, the interrelated patterns of the body segments, and the exercise performed gives a measure for designing the exercise equipment and providing the load necessary at each angle of the joint for the particular body segment.

This analysis provides a quantitative measure of the motion and allows for perfection and optimization of human performance on the exercise machine. To design the proper layout of exercise machines with the appropriate resistance lever arm in accordance with the requirements of kinesiology and the anatomy of man, designers need two kinds of data:

1. The established linear parameters of man which indicate postural relationships (static measurements).

2. The established movement capabilities of man during the exercise itself (dynamic measurements).

Static measurements are relatively simple in comparison with dynamic measurements, which require specific, often unique, design features to enable optimized muscular effort. At present only *Universal* exercise equipment is designed utilizing the dynamic forces occurring during the resistance exercise. This information allowed development of apparatus which assign different resistances throughout the range of motion in order to accommodate the biomechanical changes occurring during the exercise.

When designing exercise machines for the development of muscular strength and efficiency, it is desirable to carry out some research project to develop the needed information. Such a project can, of course, range from those of superficial nature to those of a broad-scale, even basic-research, nature. Visual inspection can in no way ascertain the numerous forces or their direction acting on the individual.

Another goal in designing exercise machines is to optimize the resultant resistance force at the proper direction. When the force is determined only perceptually, it is very likely that the design will lack maximal efficiency since guessing is involved. Far too many exercise machines are designed merely from personal observations and ideas. There still exists the absence of scientific data relating to each individual athlete and his specific performance. It is almost impossible to design an appropriate exercise machine from just an idea or observation. Whether or not an athlete is using his body efficiently on the correct equipment cannot be determined by visual observation alone.

Based on this approach, the Universal Fitness Research Department initiated designing of the *Universal Exercise Machine* based on computerized biomechanical parameters. Resistance to the different muscles is applied throughout the range of motion to maintain optimal muscular resistance throughout the biomechanical changes which take place in the range of motion. Thus, biomechanical parameters enabled development of the new variable resistance exercise machine to accomplish optimum muscular development for strength and speed.

Inquiry and research continue to unfold new avenues for perfecting and optimizing training routines for each individual sport such as track and field, or for team sports. The use of this modern computerized biomechanical analysis as a sound scientific aid in the improvement of exercise equipment helps to remove the element of doubt and the uncertainty of trial and error is replaced by accurate, scientific data — a welcome change for all who seek perfection.

2. Digitizing the data.

3. Measuring and utilizing anatomical data.

4. Utilization of the computer program for kinetic analysis and quantifying human performance.

5. Interpretation of the results.

Slow motion cinematography is used to record any desired motion and then special tracing equipment enables data to be processed directly by a high-speed computer. The appropriate programming results in a segmental breakdown of information of the whole exercise motion. Data obtained includes the total body center of gravity, segment velocities and accelerations, and joint forces and moments of force.

Computer graphic outputs of velocity, acceleration, moments of force, and muscular force curves are utilized. A unique feature allows the interpretation of the data to show the significance of contribution of each body segment to the whole motion. Other available information shows the magnitude of the muscle action at each joint, the vertical and horizontal forces at all joints, the magnitude of the shearing force at the joint, the timing or coordination of motion between the segments, and the differences due to body builds. The combination of

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