The "Bio" Side of Modern "Biomechanics"

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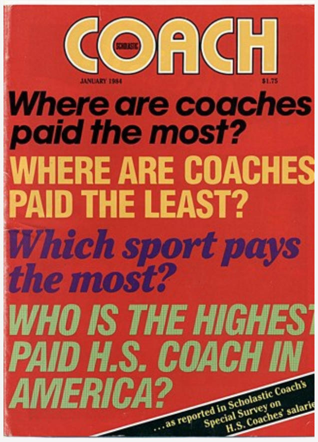

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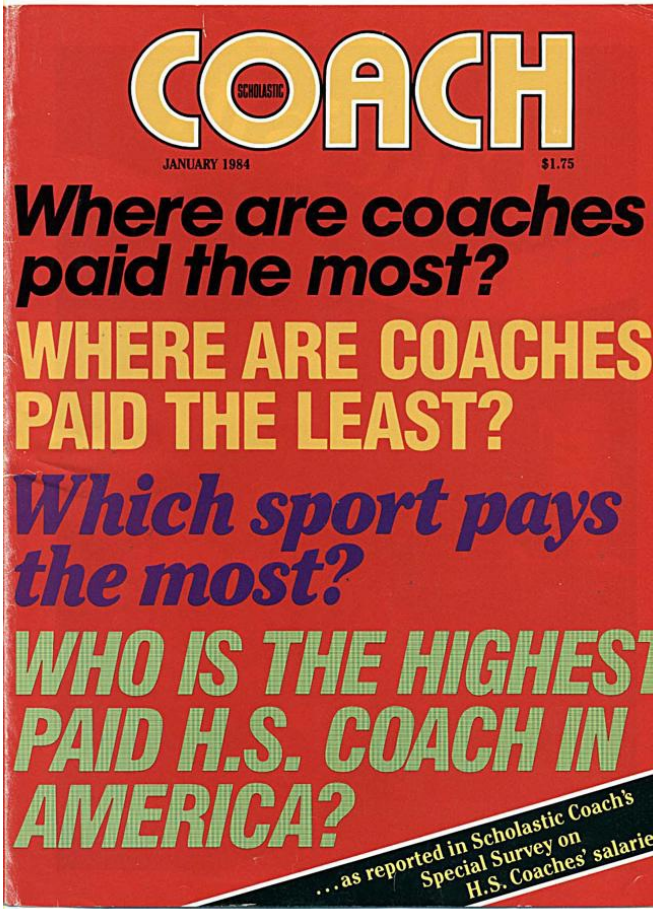
The "Bio" Side of Modern "Biomechanics"

In this article, Dr. Gideon Ariel, Chairman of Computer Sciences/Biomechanics at the U.S. Olympic Committee, discusses the importance of understanding the biological side of biomechanics for coaches. He emphasizes that high technology is not meant to replace coaches but to enhance their knowledge and equipment. He argues that coaches need to be more sophisticated in their knowledge, equipment, and techniques, and that they need to rely on sciences ranging from physiology, biomechanics, and psychology to high technology and sophisticated electronics.

Dr. Ariel also explains the basic scientific information underlying human control systems, including the role of cells, the importance of ATP for muscular efforts, and the difference between slow and fast twitch muscle fibers. He concludes by stating that proper training can improve the function of both types of muscle fiber.

Below find a reprint of the 5 relevant pages of the article "The "Bio" Side of Modern "Biomechanics"" in "Scholastic Coach":



HIGH TECH IN SPORTS

THE 'BIO' SIDE OF MODERN 'BIOMECHANICS'

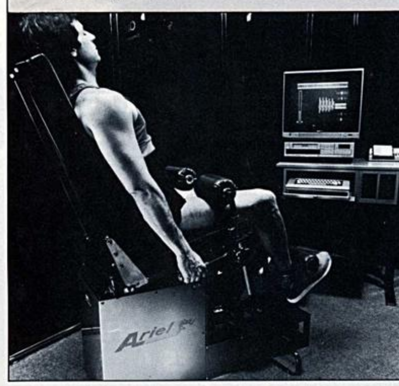
Analyzing the functioning of living organisms

By DR. GIDEON ARIEL / Chairman, Computer Sciences/Biomechanics, U.S. Olympic Committee

My previous articles discussed the impact of high technology on performance and stressed the idea that the purpose of high technology was not to replace coaches but to enhance their knowledge and equipment.

One thing is for sure: Our coaches must become more sophisticated in their knowledge, equipment, and techniques. This conclusion is consistent with the Presidential report on education, as well as with the explosion in technology.

Basic scientific knowledge will become an absolute "must" for the coach. It will aid him in the selection of athletes and in the subsequent coaching of them.



In order for the coach to achieve these goals, he will need special preparation in several areas. To analyze his athletes, he will have to rely on sciences ranging from physiology, biomechanics, and psychology to high technology and sophisticated electronics. To design the best strategies to achieve his goals, he will have to use the computer as his primary tool.

Let's look at some of the basic scientific information underlying humans and their control systems. That is the "bio" side of "biomechanics". My next article will address: the factors, both external and internal, that comprise the mechanics.

The "Bio"

Human movement occurs as a series of separate individual actions—beginning with minute electro-chemical processes of incredible speed and complication.

Our muscles are thin strands of fibers which can contract or relax because of these electro-chemical reactions. The resulting movement has a fluidity that defies even the sharpest eyes to break down.

For instance, the simplest of human movements, such as crooking a finger or raising an eyebrow, involves complex neuromuscular happenings that cannot be duplicated by artificial means. The best man-made robot still moves in jerks and stops when compared to the subtle, flowing motions of a human.

The "bio" part of biomechanics perhaps more properly belongs under the subsection of biology known as physiology—the science that deals with the functioning of living organisms.

The smallest elements of the body which maintain all the functions of life are the 100 trillion cells. The cell itself has been compared to a tiny city-state. Within its microscopic confines, the cell operates industries to support itself, transports vital supplies, and rids itself of wastes. It trades with neighboring entities, yet remains prepared to repel hostile invaders.

Cells are coded for different functions; some are liver cells, others are muscle or nerve cells, etc. But one thing is constant about cells—their basic structure or anatomy is made up of the same elements. The ways in which these elements operate (physiological processes) are also the same.

It is important to realize that the human body has remained essentially unchanged for eons. All that has changed is the environment in which it functions. Our cells have to adapt to this fast-changing world.

Our anatomy is a passive system without the physiology. That is, physiology allows the anatomy to function. The linkage between anatomy and physiology is provided by the basic commodity of energy, and the use of energy is what distinguishes living matter from dead.

The physiological processes receive their energy from the food that we eat. The fats, carbohydrates and proteins, all possess energy potentials which can be converted into energy to fuel the physiological machine.

Compound ATP

The real limitation of our muscular efforts is not oxygen, as is commonly believed, but the supply of a chemical compound called ATP. When all of the ATP is gone, there is still oxygen in the bloodstream.

Without ATP, the situation is analagous to a car engine running while in neutral. In order for the muscles to be put into gear, they must be linked to the energy-producing engine by means of ATP—the transmission of the body's energy system—which contracts the muscle fibers.

The production of ATP and its energy role relates to our aerobic and anaerobic capacity. Aerobic means ATP production in the presence of oxygen, while anaerobic means ATP production in the absence of oxygen.

However, oxygen cannot do the work alone. An efficient transportation system is also needed, beginning with the pumping of blood. Aerobic capacity, therefore, represents the efficiency of both the heart and muscle.

People who exercise regularly in endurance-type activities develop highly efficient muscles—skeletal, cardiac, and others—and biochemical reactions. The healthy person also has a different blood chemistry. His volume of blood is greater, being accommodated in a larger heart and an expanded vascular system.

The brain of all living animals serves mainly to control behavior. Only the human brain has the ability to think, create, love, etc. Thought, therefore, is not its primary purpose but, rather, just part of the complex computing mechanism required to generate and control extremely sophisticated behavior.

Sometimes, this ability to think causes inhibition in our control mechanism. This is obviously the case with athletes who fail to perform because of "mental" inhibition—"paralysis by analysis".

Some people think that the brain is a computer. However, the only computer element in the brain is the cell. Each of the 10 billion acts as a computer.

Some sensors detect touch, pressure, heat, cold, and pain.

Chemical sensors detect smell and taste.

Posture sensors detect the position of joints, tension in tendons, and length and velocity of muscle contraction.

Inertial sensors control changes in posture and acceleration of limbs as well as the relative position of the head.

Hormone, thermo, and blood chemistry analyzers report on the internal biological conditon of the whole organism.

All of this varied and continually changing information is analyzed and processed in innumerable computing centers which detect patterns, compare incoming data with stored expectations, and evaluate the results.

In many different ways and at many different levels, this sensory data stream interacts with the action-generating system to select goals, modify habits, and direct the actions of muscles, glands, and other tissue to produce what is called "behavior".

Perhaps the most obvious feature of the brain is that many computations are going on simultaneously in many different places. The brain does not execute sequential programs of instructions like a computer, but, rather, executes many parallel processes at the same time.

Muscle Groups

In addition to understanding the control of each fiber, we must understand the muscle groups as well. Muscles usually come in pairs. One is known as a flexor, the other as an extensor. When you bend your elbow, one pair of muscles contracts while the other relaxes.

A motor neuron transmission initiates the contraction, while the lack of a motor neuron transmission to the other member allows the fibers of that muscle to remain in a relaxed state.

The importance of the motor control lies not in the contraction of individual muscles, but in the coordinated contraction and relaxation of many muscles. In making a fist or grasping an object, for example, a person cannot merely flex the fingers by contracting the flexor muscles in the forearm. The extensor muscles in the forearm must also be contracted to keep the finger's flexor muscles from flexing the wrist.

The individual muscle fibers that cause a muscle to contract and relax rely on an elaborate synchronization. The arrangement permits all of them to arrive at a peak of action simultaneously.

Synchronization of muscle firing is critical for optimizing athletic performance. In the power events, such as throwing the discus or in high jumping, it is extremely important that the muscle action be simultaneously activated to optimize the force. This is done by the central nervous system sending signals to the individual muscle fibers. Lack of synchronization in power events results in lesser force and poorer performance.

On the other hand, in events of endurance, such as long-distance running, asynchronization is important, as fewer fibers are needed to maintain the action, thus permitting other fibers to "rest". In fact, the long-distance runner who "over-recruits" muscle fibers fatigues sooner. This illustrates the importance of technique in achieving optimal performance.

The question is, "How does the brain adapt to the requirement"? The answer depends upon the large number of approximations that add up to the correct signal.

The brain achieves its incredible precision and reliability through redundancy and statistical techniques. Many axons carry information concerning the value of the same variable, each encoded slightly differently. The statistical summation of these many imprecise and noisy information channels produces the reliable transmission of precise messages over long distances.

Another important factor which must be controlled is the amount of tension in a muscle. This varies according to the length of the muscle. In exercising a muscle, you'll find you can push harder when the muscle is relaxed rather than already contracted to a shorter length.

Slow/Fast Twitch

The speed with which you bring the muscle into play is another factor, as slower movement allows greater force development than fast movement. Scientists have also discovered that muscle fibers can be classified as either "slow twitch" or "fast twitch".

However, the field of histology has shown additional subdivisions and a whole spectrum of fiber characteristics. A preponderance of slow or fast twitch fibers, or an equal balance, appears to be largely a matter of genetics.

Biopsies of the tissue of world-class athletes indicate that those who lead in endurance events have a preponderance of slow-twitch fibers. Perhaps 80% of the muscles employed in their events are so characterized.

Sprinters, on the other hand, appear to have an extremely high proportion of fast-twitch fibers. This confirms the tale of the tortoise and the hare!

Distance runners thrive on slow-twitch fibers which, by contracting more slowly, consume less energy and do not fatigue as readily.

The fast-twitch fibers enable the sprinter to move his or her legs more rapidly, although a price is paid in the burning up of anerobic energy sources. For short distances, the sprinter's extravagance with energy supplies does not matter.

Recent research makes it apparent that there is a considerable diversity in the structure, biochemistry, and physiology of striated muscle fibers. Most muscles are, in fact, made up of different types of muscle fibers. Some of these are fast-contracting and others are slow.

The function of the fast-contracting fiber is perhaps obvious; it is more difficult to appreciate why muscles should have slow-contracting fibers. These slow-contracting fibers may perhaps be more efficient in certain functions.

Slow-twitch muscles are generally more economical than fast-twitch muscles in developing sustained (isometric) tension. We'd therefore expect slow fibers to be involved in maintaining posture and in movements that involve sustained tension.

When more rapid movements are required, we'd have to use fast-contracting fibers because the slow fibers are not mechanically effective at higher shortening velocities. They become inefficient once their optimum rate of shortening is exceeded.

It is thus not surprising to find that many muscles contain more than one type of fiber. In other words, muscles may possess a two- or three-"geared" system—enabling them to contract efficiently over a wide range of shortening velocities.

Could youngsters be separated into endurance-type and short-distance runners simply by studying their muscle-fiber types?

No, because most people have fairly even mixtures of fast and slow-twitch fibers. You'd think, for example, that shot-putters and high jumpers would be fast-twitch people. But they are usually characterized by a more or less even distribution of fiber types.

Investigations into slow and fast–twitch fibers are continuing. One thing seems certain, however: Proper training can improve the function of both types of muscle fiber.

There are, then, three major components of muscular contraction:

The first involves the chemical reaction that utilizes ATP.

The second relates to the force and the