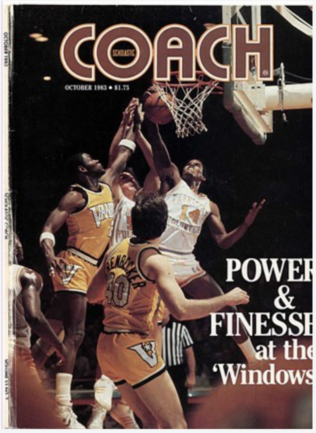
Muscular & Neural Control in Sport

When athletes mention their physical goals, they're usually content to say that they would like to do their best-incorporate their maximum speed



Code	**adi-pub-01173**
Title	Muscular & Neural Control in Sport
Subtitle	When athletes mention their physical goals, they're usually content to say that they would like to do their best-incorporate their maximum speed
Name	Scholastic Coach
Author	Gideon Ariel
Published on	Saturday, October 1, 1983
Subject	Accuracy; ACES; Analog; APAS; Biomechanics; Discus; Exercise Machine; Favorite; Journal; Performance Analysis; Science; Sports
URL	https://arielweb.com/articles/show/adi-pub-01173
Date	2013-01-16 15:40:48
Label	Approved
Privacy	Public

High Tech in Sports: Muscular & Neural Control

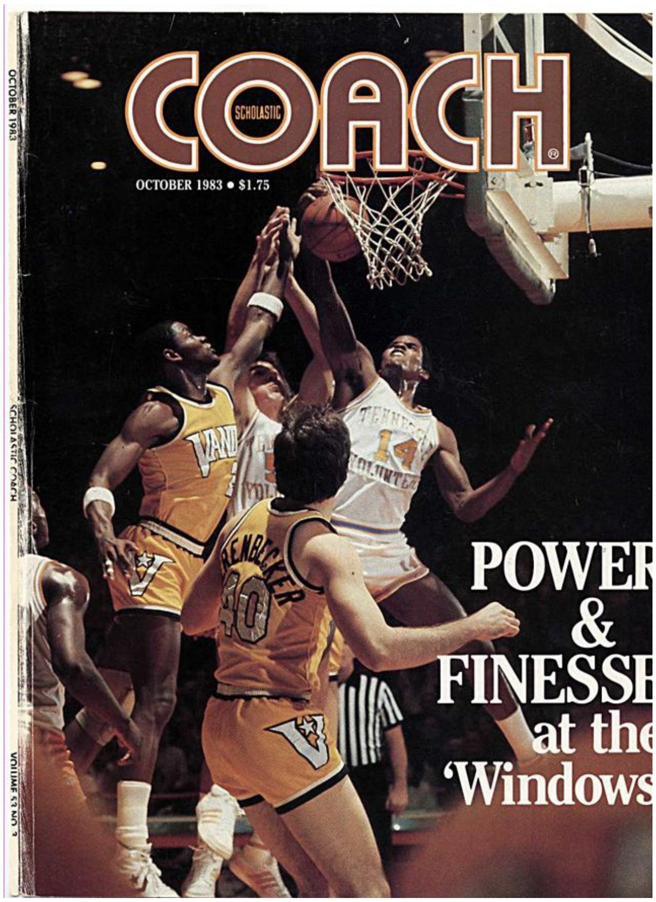
This article discusses the role of the nervous system in athletic performance. It explains that all athletic activity involves movement, which requires muscles and a signaling system that makes the muscles contract in an orderly fashion. This process is part of a field known as "biomechanics", which studies the resulting actions from combinations of electro-chemical processes in the body.

The article further explains that muscles contract by signals from the central nervous system, and that the control of muscular contraction in athletic performance is very sophisticated and highly programmed. The brain, which is primarily a control system, plays a crucial role in this process.

The article also discusses the concept of biofeedback, comparing the body's biofeedback machine to a modern computer. It explains that the brain is capable of many computations in many different places simultaneously, unlike a computer which executes sequential programs of instructions.

The article concludes by stating that modern sports sciences rely on biofeedback to enable the coach and the athlete to achieve maximum performance, and that the two main disciplines needed to achieve these goals are biomechanics and computer sciences.

Below find a reprint of the 5 relevant pages of the article "Muscular & Neural Control in Sport" in "Scholastic Coach":



HIGH TECH IN SPORTS

Performance starts in the nervous system and propagates outward

MUSCULAR & NEURAL CONTROL IN SPORT

By DR. GIDEON ARIEL
President, Coto Research Center
Chairman, Computer
Sciences/Biomechanics,
U.S. Olympic Committee

WHEN athletes mention their physical goals, they're usually content to say that they would like to do their best—incorporate their maximum speed, strength, endurance, and skill into the performance.

Athletics can be likened to a spectrum.

On one end are the explosive events such as throwing, jumping, sprinting, and weight-lifting.

On the other end are the esthetic events such as gymnastics, diving, and figure-skating, where success depends upon the ability to create movements pleasing to the judges.

In the middle of the spectrum are the endurance events, in which the athlete attempts to maintain muscular contractions at submaximal intensity levels for long periods of time.

In between these extremes are the events which require the athlete to repeatedly shoot or hit a target with a high level of consistency and accuracy.

Team sports incorporate many overlapping characteristics. The football player, for example, needs explosiveness, endurance, and accuracy.

The common denominator for all athletic activity is movement, the elementary requirements of which are the muscles and a signaling system that makes the muscles contract in an orderly fashion. (For an analysis of movement, see my article in last month's Scholastic Coach.)

Athletic performance consists of many combinations of electro-chemical processes. The science which measures the resulting actions is called "biomechanics". The "bio" part perhaps more properly falls within the area of biology known as physiology—which deals with the functioning of living organisms or their parts.

The building frames of the body are the bones, which are joined by connective tissue known as ligaments and tendons. Bones have no power to move, however. Like the frame of an automobile, they provide the basic structure upon which the body, or the engine which supplies the power to move, rests.

It is the 600 muscles of the body, accounting for about 40% of the total weight, which do the work. And it is the relationship of levers, fulcrums, muscular "power", and all of the inertial forces that constitute the "mechanical" portion of "biomechanics."

Muscles are made to contract by signals from the central nervous system. But the muscles do not respond unless they receive the appropriate simulation—and they require a given signal every time they are expected to perform.

Muscular contraction causes the joint angles to change, according to the coordination of the varying amounts of tension produced in the individual fibers. Individual cadres of these muscles surround the various joints and control the segments so that the body's actions are like a mechanical link system moved by reciprocating engines.

This intricate arrangement of bones, muscles, and neural control accounts for all muscular activities.

Performance starts in the nervous system (or in stimuli that cause activity in the nervous system) and propagates outward from there according to physical laws of cause and effect.

N.A. Bernstein in 1935 compared the workings of this human machine to a symphony orchestra:

> *Each instrument plays its individual score. So, in the act of walking, each joint reproduces its own curve of movements and each center of gravity its sequence of accelerations; each muscle produces its melody of efforts, full with regularly changing but stable details, and in like manner the whole of this ensemble acts in unison with a single and complete rhythm, fusing the whole enormous complexity into a clear and harmonic simplicity. The consolidator and manager of the complex entity—the conductor and at the same time composer of the analyzed score—is, of course, the central nervous system.*

In the 1700's, Galvanni saw that frog muscles contracted when electrically stimulated. He deduced that electrical current must be involved in the normal muscle contraction process.

While chemical-mechanical interaction operates muscles, any understanding of biofeedback requires an appreciation of biocybernetics, which is the study of control and communication in humans.

The central nervous system, headquartered in the brain, is an incredible hive of activity. Ten billion cells engage in an electro-chemical operation that, in conjunction with other body parts, permits us to see, hear, reason, imagine, create, love, hate, move, and be aware of exactly which process we are involved in through the capacity to incorporate feedback into the operation.

The building block of the system is a specialized nerve cell known as a neuron. Bundles of neurons are organized into larger entities called nerves. These serve as gateways to speed a constant stream of information from eyes, ears, nose, and other areas to the neurons of the brain, which evaluate the data in light of evolution and individual experience.

Other kinds of nerves, with special cells known as receptors, monitor such stimuli as pain, cold, touch, pressure, and even blood and body chemistry. The neurons of the brain constantly combine the data of the present with the coded information stored in the brain. They also barrage another set of special neurons, known as motor neurons, with signals.

These motor neurons within the brain and at the target sites control the movement of our muscles and the secretions of our glands. They not only trigger the chemico-mechanical process of working muscles but also try to govern the action.

BRAIN MECHANISMS

For the body to regulate movement in athletic performance, it must have information about what it controls. A servo-mechanism must be introduced to accomplish this.

Many current concepts of the brain mechanisms of movement have evolved from the work of the British physiologist, Sir Charles Sherrington, on the function of the motor neuron in certain reflexive forms of motor activity, such as athletic performance.

Sherrington's work (in the early 20th century) led to today's concept of the "triggered movement" based on a "central program" involving a spinal rhythm generator.

Many current investigations of the neurophysiology of locomotion are aimed at clarifying the interaction between what may be termed "central programs" from the brain and "sensory feedback" from outside the nervous system.

Sherrington introduced the term "proprioception" to describe the organism's detection of stimuli by the receptors.

There are two kinds of muscle proprioceptors. One senses elongation; the other, tension. The length receptors of muscles send fibers into the spinal cord to form synapses on motor neurons that terminate on the same muscles.

Hence, any increased length receptor activity that results from muscle elongation activates the motor neurons of the elongated muscle. This, in turn, gives rise to a muscular contraction that opposes elongation.

The tension receptors sense force rather than elongation. Their activation leads to the inhibition of the associated motor neurons. Thus, when an increase in muscle tension activates these receptors, their response acts on the associated motor neurons and gives rise to a reduction in force.

> **Though the brain is primarily associated with the process of thinking, it is first and foremost a control system.**

Both the length receptors and the tension receptors may, therefore, be viewed as components of what an engineer would call a negative feedback control system. This particular system maintains its stability by resisting changes in muscle length and tension.

These control mechanisms in the muscles and tendons themselves are governed by higher level mechanisms in the brain. In fact, the control of movement relies on hierarchical control. The sensory information in the muscle itself processes local information and transmits net results to higher centers.

Feedback enters the hierarchy at every level. At the lowest levels, the feedback is unprocessed and, hence, is fast acting with a very short delay. At the higher levels, feedback data pass through more and more stages of an ascending, sensory-processing hierarchy.

Feedback thus closes a real-time control loop at each level in the hierarchy. The lower level loops are simple and fast acting. The higher level loops are more sophisticated and slower. The combination generates a lengthy sequence of behavior which is both goal-directed and appropriate to the environment.

Such behavior appears to be intentional or purposive. The top level input command is a goal, or task, which is successively partitioned into subgoals, or subtasks, at each stage of the control hierarchy until, at the lowest level, output signals drive the muscles and produce observable behavior.

HIERARCHAL CONTROL

The success or failure of any particular task, or goal-seeking action, depends on whether or not the higher level functions are capable of providing the correct information. This hierarchial control is necessary so as to direct the output to the lower level for successful performance despite perturbations and uncertainties in the environment.

Small perturbations can usually be corrected by low level feedback loops, as was described for the length and tension sensors. These involve relatively little sensory data processing and, hence, are fast acting.

Larger disturbances, due to changes in the environment or perhaps to execution of a difficult activity, may overwhelm the lower level feedback loops and require strategy changes at higher levels in order to maintain the system within the region of successful performance.

Thus, a highly skilled and well-practiced performer, such as a gymnast on a balance beam only four inches wide, can execute extremely difficult maneuvers with apparent ease.

Many such activities seem to be performed with a minimum of physical and mental effort. The performances are often described as "effortless" or "done without even thinking".

What is really meant is that the athlete's lower level corrections are so quick and precise that the performance does not deviate significantly from the ideal. There is never any need for higher level loops to make emergency changes in strategy.

On the other hand, a novice gymnast may have great difficulty in even executing a performance. He or she is continually forced to bring higher levels into play to prevent failure, and even the slightest deviation from the planned or desired motion will result in a loss of balance.

He or she works very hard, and often fails. Because the responses are late and often misdirected, the performance is erratic and rarely resembles the ideal.

Practice enables the athlete to perfect the mistimed functions and to create the capacity to reprogram the movement more efficiently.

The degree and precision of these corrections, and the method by which they are computed, determine the rate at which the learning process can produce an efficient and successful performance.

The control of muscular contraction in an athletic performance is very sophisticated and highly programmed. Consider, for example, the highly skilled matter of signing one's name.

Whenever Mr. Smith signs his name, it is consistent enough to be recognizable and different enough to prevent anyone else from accurately duplicating it. The individuality always remains.

This complex handwriting movement possesses a pre-programmed control mechanism. Optimum performance likewise depends on the control efficiency. It does not matter how strong the muscles are or how efficient the metabolism. The neural control of the muscles in executing the skill is the most important factor.

A CONTROL SYSTEM

Most people associate the brain primarily with the process of thinking. Yet research shows it to be first and foremost, a *control system*. Thought is *not* the primary purpose of the brain. It is, rather, an artifact that rises out of the complex computing mechanism required to generate and control extremely sophisticated behavior.

Sometimes, this ability to think causes inhibition in our control mechanism. Consider the athletes who fail to perform due to "mental" inhibition, or what we call "choking".

BIOFEEDBACK FUNCTIONS

The biofeedback machine in the body may be compared with the modern computer. However, the single computer element in the brain is the cell. Each cell acts as a computer, and there are 10 billion of them. The vast quantities of feedback information is analyzed and processed in innumerable computing centers—which detect patterns, compare incoming data with stored expectations, and evaluate the results.

One of the main differences between the brain and a computer is that the brain is capable of many computations in many different places simultaneously, whereas the computer executes sequential programs of instructions.

The biofeedback functions are executed in two basic ways. In the first, a signal is broken into many values which can be added to other numbers. This is the way a computer adds signals. It is called digital processing.

The other method is called analog, and the brain relies on this method for its fundamental computations. Analog computers perform operations by the addition of continuous signal values.

Each neuron in the brain is essentially an analog computer performing complex additions, integrations, differentiations, and nonlinear operations on input variables that can number from one to several hundred thousand.

The brain is a digital device only in that information is encoded for transmission from one neuron to another over long transmission lines, called axons, by pulse-frequency or pulse-phase modulation.

When these pulse encoded-signals reach their destinations, they are reconverted into analog voltages from the computations which take place in the dendrites and cell bodies of the receiving neurons.

Success in a particular event, whether for explosive, endurance, or esthetic purposes, depends on the motor programming that initiates a proper biofeedback signal to the motor pool.

Individual muscle fibers make a muscle contract and relax in an elaborate synchronization. The arrangement permits them all to arrive at a peak of action simultaneously. But certain recruitment patterns characterize each event in a unique way.

The synchronization of muscle firing is critical for optimizing many performances. In the power events, such as discus throwing or high jumping, it is extremely important for the muscle actions to be simultaneously activated to optimize the force. The lack of synchronization in the power events results in lesser force and poorer performance.

On the other hand, in endurance events such as long-distance running or cross-country skiing, asynchronization is important since fewer fibers are needed to maintain the action, thus permitting alternating fibers to "rest".

It's true that some long-distance runners may "over-recruit" muscle fibers and, therefore, fatigue sooner—emphasizing the importance of technique in achieving optimal performance.

The question arises as to how the brain adapts to the specific activity requirements. The answer relies on the great number of approximations that must form the correct signal.

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

In a similar way, a multiplicity of neurons may compute roughly the same input variables. Clusters of such computing devices provide statistical precision and reliability orders of magnitude greater than that achievable by any single neuron.

The outputs of such clusters are transmitted and become inputs to other clusters, which perform additional analog computations.

Since the model of ideal performance consists of fantastic complexity, modern sports sciences rely on biofeedback to enable the coach and the athlete to achieve the maximum performance.

The two main disciplines needed to achieve these goals are biomechanics and computer sciences.