Fast-Twitch, Slow-Twitch Muscle

By JOHN P. KALAS, M.D.
Chief, Department of Pathology,
West Volusia County Hospital, Florida

(If you believe there is a difference between fast-twitch and slow-twitch fibers in humans . . . and if you train your athletes accordingly . . . *you need to read this article.)*

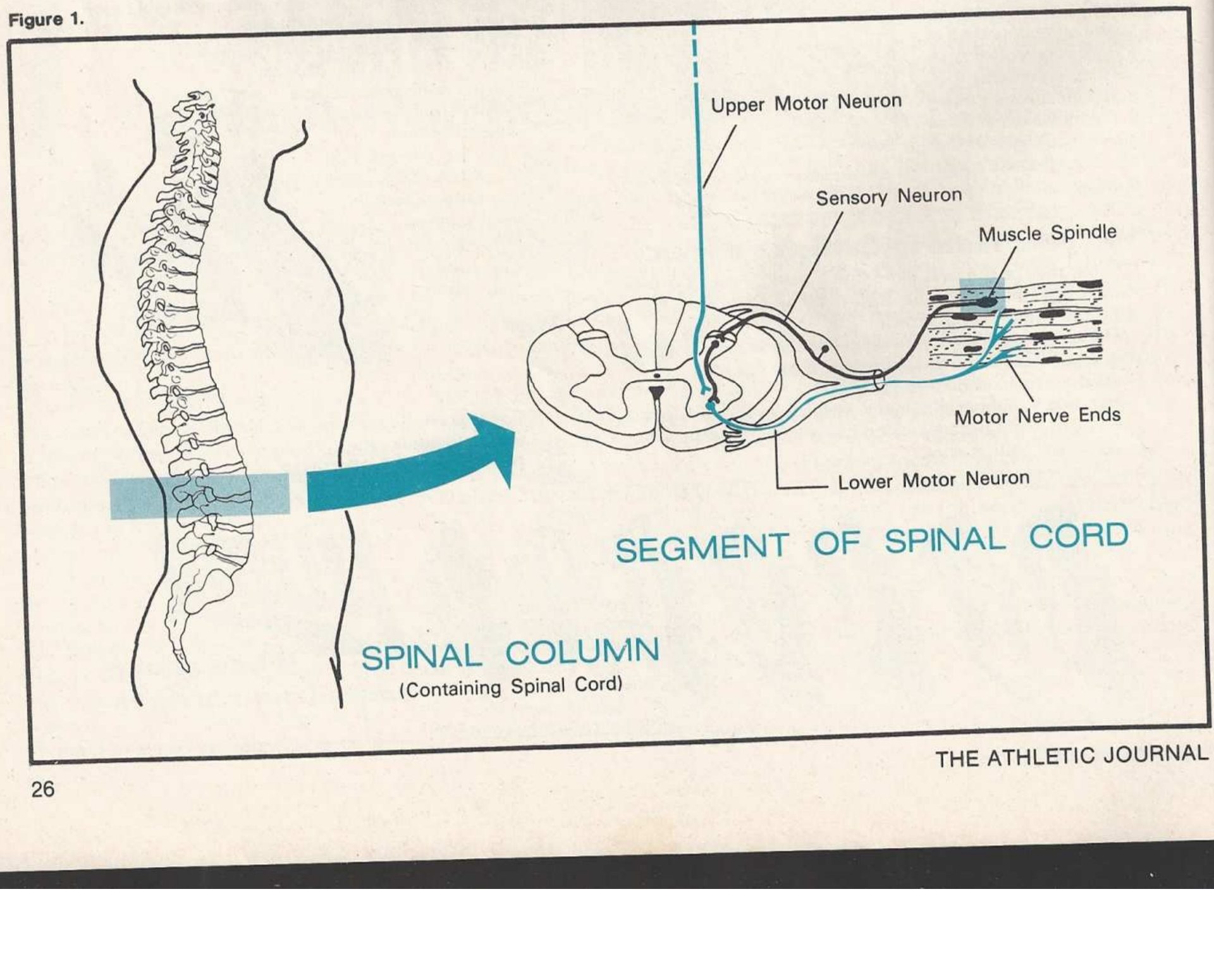
MY interest in muscle structure and function stems from my participation in high school athletics. This interest was carried through college, medical school, a three-year residency in internal medicine, a year research fellowship in physiology, and finally a four-year residency in pathology. During my residency in pathology, I had considerable exposure to muscle physiology at the Armed Force Institute of Pathology. My background includes a full 10-year period at the Walter Reed Army Medical Center and some 50 published research studies.

It is unfortunate that people with my experiences, or similar experiences, cannot have personal associations with coaches and physical educators such as those who have done some work and are attempting to combine the disciplines of muscle physiology and athletics. This is a common situation that exists in all areas. For example, the massive amount of knowledge regarding muscle structure and function staggers all imagination. There is so much knowledge in this area that it would literally be impossible for any one person to even assemble all the available information, much less make it meaningful.

The laboratory scientists communicate with each other, but rarely with physicians in the field of disease rehabilitation. These physicians have knowledge that is easily interchangeable with coaches. Unfortunately our society keeps most of us (laboratory scientists, physicians, and coaches) so busy that we are unable to communicate in a productive manner with each other. This massive amount of knowledge, thus, remains disjointedly scattered throughout the literature without the basic information ever reaching the athletes.

In February of 1976, I decided to attempt to integrate these three broad areas. Since making this decision, I have investigated the athletic literature and have made inroads in developing relationships with various athletes and coaches. One particular aspect of muscle physiology seems to be a recurring topic of discussion in almost every jour-

Figure 1.



Fibers: What Is the Truth?

nal I read or every seminar I attend. Although this topic is very complex, it is usually referred to as the concept of *fast-twitch, slow-twitch muscle fibers.* And, as usual, attempts to simplify complicated subject matter frequently lead to misunderstanding. This has certainly been the case in the fast-twitch, slow-twitch area.

In order to provide you with a better understanding of the general area of muscular contraction (as well as the specific concept of fast-twitch, slow-twitch), I will do my best to answer some misunderstood questions. But let me caution you, there are no simple, easy-to-understand answers to most of the questions. So please bear with me as I try to unravel the basic factors.

How does a muscle contract?

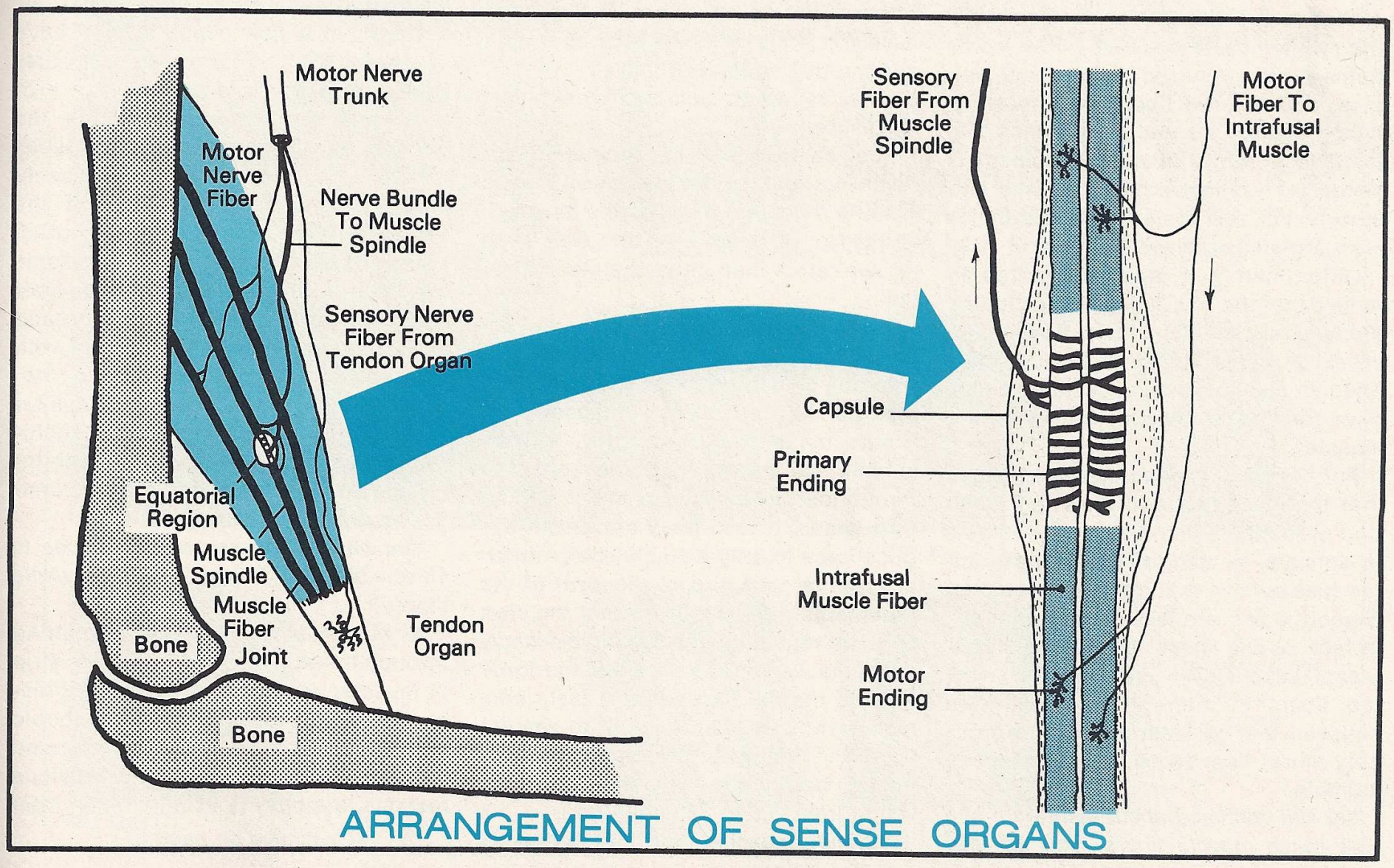
The answer is theoretical and complicated. There are, however, three major areas that can be discussed with relative certainty.

The first way a muscle contracts is through a conscious command from the brain. Obvious examples are to decide to flex your biceps or extend your leg. The command from the brain is transmitted by the upper motor neuron, which is part of the spinal cord, to the lower motor neuron (see Figure 1). This in turn stimulates the muscle to contract. Thus, the biceps flexes or the leg extends. The impulse that travels along the nerve trunks named above is of an electrical nature similar to the electrical impulse that turns on your house lights or refrigerator.

The second way a muscle contracts is through what is called a "reflex arc." The knee jerk is an example of an activated reflex arc. It is performed by crossing the legs. The top leg is then tapped by some object in the area of the knee cap (quadriceps tendon). The result is a knee jerk. This action does not involve the upper motor neurons. It is mediated by activation of the tendon organ and the muscle spindle, which in turn activates the sensory fiber and finally reaches the lower motor neuron (see Figure 2). The lower motor neuron then causes the muscle to contract as it did in the first example. But, in this case, it is done without a command from the brain. The upper motor neuron, by command from the brain, can, however, suppress or modify the knee jerk. For example, if you choose not to allow your knee to jerk when the tendon is tapped, you can send a signal from your brain to the lower motor neuron and prevent the impulse from traveling to the muscle. Conversely, if the upper motor neuron is cut, the knee jerk is exaggerated. This would indicate that the upper motor neuron modifies the reflex arc.

The third method for muscle contraction to occur is through conditioned reflexes. These are extremely complicated and are best demonstrated by animal experiments. The experiments date back to the Russian scientist, Ivan Pavlov, who demonstrated that animals could be reinforced to perform certain actions of conditioned reflexes. One experiment cited is that upon ringing a bell, a dog

Figure 2.



ARRANGEMENT OF SENSE ORGANS

can be conditioned to push a lever that will open a box containing food. Conditioned reflexes happen in all forms of athletics. One might consider a rapid return of a tennis ball by a player close to the net conditioned since he barely had time to think about what to do.

Considering only the three major portions of nervous activity that cause muscles to contract, one can readily visualize that all three: the command from the brain (upper motor neuron), tendon reflexes (reflex arc), and conditioned reflexes (Pavlov's experiments), would have to be involved in the training of an athlete for him to utilize his muscle contraction for his specialized sport.

Even more complex is the mode by which the muscle itself contracts. Albert Szent-Gyorgyi, the famous Hungarian biochemist, demonstrated that the chemicals, actin and myosin, contract in the presence of adenosine triphosphate (ATP). Later it was determined that this contraction is modified by some 70 or more enzymes and/or chemicals. This is a rule that applies whether the muscle is red or white or slow or fast. Furthermore, this underscores the complexity of the problem of muscle contraction when it is considered along with the influences of the nervous system.

How do the concepts of fast-twitch, slow-twitch muscle fibers relate to athletics?

Classically, the fast-twitch fibers are the white muscle fibers that some authors have referred to in recent articles, and the red fibers are the slow-twitch fibers. One author contends that fast-twitch, white fiber development is necessary for fast athletic activity and slow-twitch, red fibers are necessary for slow athletic activity.

Unfortunately it is demonstrated in nature that the non-flying domesticated animals, such as chickens, have white breast muscles and dark leg muscles. The fast flying wild fowl, such as ducks, have red breast muscles but white leg muscles.

Furthermore, most authorities believe that there are fast and slow red fibers and probably fast and slow white fibers in animals. In man, however, these authorities believe that the differences between the two are less than in animals. In fact, *no one knows* the exact distribution of fast or slow white and fast or slow red fibers in man. In addition, it is believed that at least eight (and probably more) fiber types are prevalent in animals.

I'm still confused about fast-twitch and slow-twitch muscle fibers. How do they relate to supplemental exercise?

The important factor to remember is that there is no hard and fast rule about white and red fibers in reference to their physiological activity. One cannot infer that just because a fiber is white it is a fast-twitch fiber, or that a red fiber is a slow-twitch fiber.

Muscle fibers have been completely reclassified in animals. The most recent classification, according to Dr. Victor Dubowitz (Professor of Pediatrics, Royal Post-Graduate Medical School, London, England) and Dr. Michael Brooke (Associate Professor, Division of Clinical Neurology and Director of the Muscle Clinic, University of Colorado Medical Center), includes at least eight different fiber types. An animal is born with type I and type IIC fibers. The type IIC fibers give rise to the adult IIA and IIB. The IIA is a fast-twitch, red fiber, while the IIB is a fast-twitch white fiber. The type I fiber is a slow-twitch, intermediate fiber. The remaining fiber types are not as well delineated.

In other words, it is impossible to simplify the complicated classification of muscle fibers into white fast and red slow. It is equally impossible to simplify muscular contraction into fast exercise for faster movement and slow exercise for slower movement. *Coaches, therefore, should not have their athletes perform "fast exercise for fast muscles," . . .* without first being aware of the problems. Performing fast repetitions is both dangerous and unproductive.

What is wrong with performing fast repetitions?

First, so there is no misunderstanding, I want to define what I mean by "fast." When a repetition exceeds the muscle's ability to contract, or the weight is thrown rather than lifted, then that is too fast.

As an example, let us examine a barbell press being performed by a subject standing on a force plate connected to a recorder. If the subject presses and lowers the barbell in a slow, smooth manner, a steady force is recorded throughout the entire movement. On the other hand, a fast, jerky movement applies force to only a small portion (usually at the start and at the end) of the repetition. In other words, after the start of a fast repetition, *the barbell is actually lifting the subject's arms.* Plus, the force applied during the start of a fast, jerky movement can often amount to several times the weight of the barbell (a 100-pound barbell for an instant could weigh from 200 to 300 pounds).

Yanking muscles (and that is exactly what is happening) does not build strength. Instead, it exposes the joints, muscles, and connective tissues to danger. Force causes injury, and throwing a weight certainly increases the force.

So, for the best results from exercise, have your athletes perform slow, deliberate repetitions. Have them raise the weight smoothly (without acceleration), pause briefly in the contracted position, and lower the weight slowly and under full control. As a rule of thumb, it should take from one to two seconds to raise the weight, and slightly longer to lower the same weight.

What is a motor unit?

The motor unit is made up of the lower motor neuron and the muscle fiber that it activates. More specifically, a motor unit is made up of a lower motor neuron and a type I, IIA, or IIB fibers. Motor units are not mixed, although a muscle may contain a mixture of motor units. This has been determined for animals, but not in man.

In fact, it is now believed that there is a continuous spectrum of motor units with differing speeds of contraction that are directly related to the diameter of the nerve fibers. Future investigations, therefore, should center around the inter-relationships between the muscular system and the nervous system (see Walton's book).

Are the muscle fiber types in man different from those found in animals?

The muscle fiber types in man have not been well defined. As previously stated, it is believed that as one progresses up the phylogenetic scale, the differences in muscle fiber types diminish. In fact, only a few muscle biopsy specimens have supplied the data that have resulted in the broad, sweeping conclusions drawn by some coaches. Until the distribution of fiber types in each of the muscle units and groups are typed histochemically with corresponding physiological and biochemical studies accomplished, similar to those performed in animals, conclusions regarding fast or slow fiber involvement in exercise and training cannot be drawn.

You have made several references to muscle biopsies. Exactly what is a muscle biopsy?

A muscle biopsy consists of cutting through the skin and taking a small strip of muscle, usually for diagnosis of disease states by chemical or microscopic techniques. It can also be performed with a large bore needle. For obvious reasons, a biopsy is usually taken from

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hurdlers, can and will develop 15-second hurdlers from average sprinters, and possibly produce a few outstanding hurdlers.

A well-trained hurdler is durable. In our eight years of working directly with high hurdlers, only two athletes suffered an injury in a hurdle race, and of the two, one was due to weather conditions.

The strength, speed, and relaxed sprinting technique gained from hurdling provide the material from which good jumpers are made — high, long, and triple. With a hurdler as a jumper, a coach need not have the same fears he might experience when his star sprinter slams his foot down on the takeoff board. Hurdlers injured jumping, in our experience, are as rare as hurdlers who are injured while hurdling.

Finally, the strength gained from hurdling itself, as well as the development of an increased, relaxed stride, has to produce better sprinters. A coach may unwittingly defy the American theory that sprinters are born, not made. Actually, it all depends on what he considers a sprinter.

When it has an abundance of well-trained hurdlers, a team is bound to win more than a fair share of medals in these contested events. With athletes such as the ones mentioned in the two charts, we managed to win eight hurdles relay titles over a three-year period. And the highlight of relay efforts came in the high hurdles when the trio of John H., John G., and Stu E. established a State Indoor Sectional record of 23.5, besting the efforts of perennial large school powerhouses, Mount Vernon and New Rochelle. Except for John H.'s 7.4, the other legs were average, but adequate enough to defeat the opposition and establish a record. AJ

Muscle Fibers

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the surface of the muscle.

For the determination of fast as opposed to slow-twitch, muscle fibers or white fibers as opposed to red fibers, entire cross-sections of muscle with corresponding physiological studies would be necessary. This is not practical or possible in man. In order to make some inroads in this area, without taking complete cross-sections of muscle, would mean taking at least three levels of biopsies from many muscle groups. And at each level, several hundreds of biopsies would be necessary for statistically significant muscle counts to be made. Remember, *literally nothing* is known about white and red muscle distributions in humans.

As a coach, what guidelines can I use to apply these physiological principles to the training of my athletes?

First of all, I would like to re-emphasize that there is no clear distinction between fast-twitch (white) and slow-twitch (red) muscle fibers in man. For some coaches and physical educators to say there is a difference, and in turn train athletes according to these differences, only means that they have over-interpreted the histochemical studies that have been used to classify white and red fibers.

From my many experiences and studies, coaches and athletes should use the following factors as safe guidelines in performing supplemental exercise.

1. Since acceleration increases force and force is the primary cause of injury, slow, deliberate exercise style (about 1 to 2 seconds on the lifting portion of the movement and slightly longer on the lowering portion) is best for supplemental training. Remember, the weight should be lifted, not thrown.

2. Building strength is one thing. Exhibiting strength is an entirely different

matter. Your athletes (unless they are competitive weight-lifters) should be only interested in building strength. Muscular strength is best built by the performance of one set of about 8 to 15 slow repetitions, of no more than a dozen different exercises . . . rather than trying to perform multiple sets of fast, maximum-attempt repetitions.

SUPPLEMENTAL READING

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The Female Athlete

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scholastic level in track and cross-country. Some evidence indicates that the female may have mood changes in response to the menstrual cycle. However, this does not indicate that she cannot compete or train at these times. Although it may appear that the female is more emotional than the male, no difference is indicated between the male or female athlete in being able to exercise control and cope with stressful competitive situations. The myth that only unattractive women participate in athletics has been reversed and perhaps this is a major psychological factor in the increased participation of the female in track and cross-country.

COACHING THE FEMALE RUNNER

Who should coach a girls' track or cross-country team has been a topic of controversy. There are three alternatives. One is a separate female team with either a male or female coach or a common coach for both the male and female teams. In some larger school programs, an assistant coach is designated to handle the girls' team for meets while the entire staff shares the coaching duties during training. Another method is to combine the two coaching staffs and train both teams jointly. The most important aspect of coaching a girls' team is not whether a male or female should coach, but which person is most qualified and capable of doing the best job.

THE FEMALE COACH

In most respects, it would be best if a female coached a girls' team. This would allow fewer restrictions in contact with the athletes and also provide an image of her own sex for the female runner to look up to and associate with. Presently, more experienced and qualified women coaches are needed for track and cross-country coaching at the high school level. In time this will change as more women are participating in these sports who will become future coaches.

The role of the female track and cross-country coach is no different from that of her male counterpart. She should