BIOCHEMICAL FOUNDATIONS OF ATHLETES' PHYSICAL QUALITIES MANIFESTED DURING MUSCULAR ACTIVITY

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https://doi.org/10.5281/zenodo.17608293

ARTICLE INFO

Received: 12th November 2025
Accepted: 13th November 2025
Online: 14th November 2025

KEYWORDS

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ABSTRACT

The physical qualities of an athlete manifested during muscular activity (strength, speed, velocity, power, endurance, etc.) depend on the biochemical, physiological, morphological, and genetic characteristics of the individual, as well as the specifics of their psychological, technical, and tactical preparedness. The force developed by a single muscle fiber is directly dependent on the content of contractile proteins within it: the total amount of actin and the degree of myosin polymerization. In other words, the magnitude of the effort generated in a contracting muscle is directly proportional to the number of cross-bridges between actin and myosin filaments within each sarcomere comprising the myofibrils.

The physical qualities of an athlete manifested during muscular activity (strength, speed, velocity, power, endurance, etc.) depend on the biochemical, physiological, morphological, and genetic characteristics of the individual, as well as the specifics of their psychological, technical, and tactical preparedness. The force developed by a single muscle fiber is directly dependent on the content of contractile proteins within it: the total amount of actin and the degree of myosin polymerization. In other words, the magnitude of the effort generated in a contracting muscle is directly proportional to the number of cross-bridges between actin and myosin filaments within each sarcomere comprising the myofibrils.

The rate of formation and rupture of cross-bridges in the myofibrils of skeletal muscles, along with the associated speed of tension development and muscle contraction, depends on the ATPase activity of myosin-that is, the rate of enzymatic ATP hydrolysis by myosin ATPase, which varies significantly across different types of muscle fibers. It is higher in white (fast-twitch, FT) fibers than in red (slow-twitch, ST) fibers. As noted earlier, human skeletal muscles contain FT and ST fibers in varying proportions. Changes in the FT-to-ST ratio directly affect the functional properties of the muscle. These muscle fibers are components of different motor units and are innervated by distinct motor neurons. The higher the percentage of FT fibers in the working muscles, the greater their speed-strength qualities.

From the above data, an important pattern emerges: the magnitude of maximum muscular effort (muscle strength) is directly proportional to the sarcomere length or the length of thick myosin filaments-that is, the degree of polymerization of the primary contractile protein, myosin-and the total actin content in the muscle. In other words, the force developed during the interaction of actin and myosin filaments in myofibrils is directly proportional to the number of cross-bridges formed between them or the area of their overlap. The greater the number of cross-bridges formed, the greater the force developed within each sarcomere.

The longest sarcomeres are found in the adductor muscles of mollusks, while the shortest are in the flight apparatus of insects and hummingbirds. Mollusk adductor muscles can generate muscular force 3-6 times greater than the maximum human muscle strength. Conversely, the maximum force developed by the flight muscles of insects and hummingbirds is approximately 3 times less than that of humans. As previously mentioned (see Chapter 1), in human skeletal muscles, sarcomere length averages 1.8–2.5 μm, and myosin filament length is about 1,500 nm. Sarcomere length, or the degree of myosin polymerization in thick filaments of myofibrils, is a genetically determined factor, as it does not change during individual development or under the influence of training. However, sarcomere length exhibits certain variations in fibers of different types within various muscles.

At the same time, the content of the other contractile protein-actin-in muscles changes significantly during individual development and under the influence of sports training. Actin content in myofibrils has a linear relationship with the total creatine amount. Determining actin quantity is a complex and labor-intensive process and is not always precisely measurable. Therefore, in sports practice, the total creatine concentration in muscles or blood is more commonly used to monitor muscle strength development and predict performance levels in speed-strength exercises.

Thus, it can be concluded that the biochemical basis of strength lies in the total content and enzymatic properties of muscle contractile proteins-that is, the degree of myosin polymerization, its ATPase activity, and the total amount of actin.

The biochemical prerequisites for speed (contraction velocity) are largely the same as for strength: high content of contractile proteins and elevated myosin activity as an enzyme that hydrolyzes ATP. However, unlike strength, maximum contraction speed is inversely proportional to sarcomere length or the length of thick myosin filaments and directly proportional to relative ATPase activity. Like strength, maximum contraction speed values differ significantly across muscle fiber types: in FT fibers, they are nearly 4 times higher than in ST fibers.

It should also be noted that high contraction speed depends greatly on the ability to rapidly resynthesize ATP, primarily via the creatine kinase reaction, as well as the concentration of Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+} ions and their rapid binding and release.

Based on the above, it can be concluded that the biochemical basis of speed (contraction velocity) is linked to the activity of myofibrillar contractile proteins, particularly myosin ATPase activity-that is, the rapidity of chemical energy mobilization. Unlike strength, maximum contraction speed is inversely proportional to sarcomere length or the length of thick myosin filaments within a single sarcomere: the higher the contraction speed, the shorter the sarcomere length. Additionally, ATP resynthesis via the creatine kinase reaction plays a significant role in speed qualities.

In voluntary human movements, the isolated manifestation of strength and speed is less critical than their combined effect, evaluated by the power of the developed effort. Muscle power is a linear function of total ATP ase activity-that is, the overall rate of ATP hydrolysis. Maximum power values, like maximum contraction speed, differ substantially across muscle fiber types and change noticeably during adaptation to specific motor activities. In fast-twitch white fibers, maximum power reaches 155 watts per kg of muscle weight; in slow-twitch red fibers, it is 40 watts per kg of muscle weight..

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