QUICKNESS AND VELOCITY IN SPORTS MOVEMENTS

By Prof. Yuri V. Verkhoshansky

The author makes a distinction between quickness, which describes a rapid movement entailing little resistance or muscular effort, and velocity, which relates to movements requiring a considerable output of energy and against high resistance.

The important characteristic of movement quickness concerns the specific capacity of the central nervous system to regulate efficiently psychomotor function. Several examples of this type of movement are given.

Movement or locomotion velocity, in contrast, is based on the regulatory neurophysiological mechanisms and on the necessary metabolic processes. The operation of these mechanisms and processes is explained and recommendations made as to how they can best be adapted to training for speed of locomotion.

1. Introduction

Sports technicians have always paid great attention to speed of movement and locomotion. However, this issue now requires fresh elaboration from the standpoint of both theory and practice. If you ask a coach what is the most important aspect of an athlete's preparation, answers may vary, but most coaches will immediately indicate speed of movement and locomotion.

Is this outlook correct? I believe it is. Speed of movement is a typical effect of exercise — the result of training — in most sports. Indeed, speed of execution is the decisive element in a sprinter's run, as it is in a boxer's punch, or again in a discus thrower's performance.

The degree of importance a coach ascribes to the various training goals is always significant. The goals, the number of which is inversely related to the coach's experience, constitute a practical translation of what the coach wishes to achieve. They, therefore, indicate his conception of the general strategy and methodology of training.

Human movements of brief duration can be qualitatively distinguished by means of two concepts: quickness and velocity. The distinction is of the utmost importance but, in the scientific and methodological literature, these terms are often used as if they were synonymous. On a practical level this hinders a rational organization of the training process.

Movements of brief duration can be performed under two different conditions. In the first instance, when the motion does not require a great expenditure of strength or of energy, it occurs mainly through the speed with which it is conceived and implemented in the motor cortex of the brain. For example, catching a fly requires only a lightning, accurate movement that will catch it unawares.

The second instance concerns all the movements requiring a significant expenditure of energy and muscular effort. In this case, the muscles are involved in a prolonged effort on account of great external resistance. For example, a powerful athlete will lift a barbell of a given weight faster than a less powerful athlete, a cyclist with greater endurance will go from A to B in less time.

The difference lies in the physical nature of these movements. We must note that the functional capacities involved in brief movements have little or no part to play in movements requiring strength, and vice versa. In the first case, quickness is the specific functional capacity involving the athlete's psychomotor skills, while in the second, speed of movement or locomotion indicates the degree of the athlete's special preparation.

2 Movement quickness

What exactly is movement quickness? It should be possible to find a thorough explanation in the countless works dedicated to human motor skills, but a careful study of the available literature provides only vague, contradictory and often dubious information.

Very little research has been carried out in this direction and the issue has not been examined with a scientific approach. F. HENRY (1954—66), W. LOTTER (1962), D. CLARKE (1962) and E. FLETSHMAN (1962) were the first to investigate quickness as an athlete's specific motor skill.

Studies by the above scientists helped to clarify the issue, by explaining that the capacity to perform quickly elementary motor tasks is only very slightly connected to the ability to impart velocity in more complex movements involving more than one joint. They have shown that quickness is fully involved in movements that do not require a significant strength or energy expenditure or difficult co-ordination. The physiological mechanism of quickness is associated with the multifunctional capacity of the motor cortex of the brain.

Therefore, according to these studies, quickness must be considered as the specific capacity of the central nervous system to regulate efficiently psychomotor function; in other words, as the capacity to perform quick movements that do not encounter great external resistance or require great energy consumption.

Slow Twitch Fibers (STF) and Fast Twitch Fibers (FTF) have different contractile and metabolic characteristics; movement quickness depends on which of the two are primarily aroused. It has been established that an athlete whose muscle fibers are predominately FT has higher parameters of speed of movement and strength. For example, a sprinter's muscles contain a higher percentage — up to 75% — of FTF, while a distance runner's muscles contain a higher percentage of STF — up to 90%.

The limiting factor as regards quickness is determined by the individual characteristics of the nervous system. Athletes whose nervous system has a low strength threshold, i.e. those who are excitable and impulsive, are quicker.

Quickness can be fully expressed in a movement only if the athlete has a significant energy supply. Therefore, in disciplines in which the athlete encounters high external resistance, it is necessary not only to train quickness but also to develop the functional systems involved in achieving maximum speed in the performance of a given movement. It is a question of muscle potential and the efficiency of the metabolic processes. When quickness of movement does not require endurance or strength, high work volumes are inadequate — work volumes for high level sprinters are usually low.

The following are specific examples of quickness of movement:

- A short latent period of muscular reaction;
- Quickness in performing a simple, isolated movement (no overloads), with an upper limb, a lower limb, the trunk or head;
- Quickness in performing a movement involving more than one joint and requiring a variation of body position in space, or the transition from one action to the other, without great external resistance;
- The rate of a movement without overload.

These qualities are only slightly related to one another, or related to the degree of physical conditioning. No significant correlation has been found between an athlete's quickness of movement and the speed of a movement involving a significant muscular effort. The relative independence of these qualities of quickness can be observed quite early, when the athlete is between 9 and 13 years of age.

The latent period of a movement reaction is the delay of a spontaneous reaction in response to a given stimulus. We must distinguish simple movement reactions from complex movement reactions.

In the first case, perception is simple (perception of the appearance, variation and disappearance of a stimulus). In the case of a complex reaction, perception includes the choice of an adequate response.

Studies carried out in different sports show that the latent period for a simple movement reaction is an expression of quickness. It is genetically predetermined, it does not respond to training and it is not related to the athlete’s degree of preparation. It cannot therefore characterize an athlete’s speed. The latent period for a simple movement reaction is influenced by two factors: the regulation of the neuro-motor apparatus and the motor structure of the movement. Since the former cannot be significantly improved, training to improve the overall latent period will have to concern the latter. There is no significant interdependence between the act of reception and the action proper. Individual differences in reaction time are greater than differences in action time and this signifies that there is little correlation between them.

A complex motor reaction in sporting activities requires an evaluation of the situation and the choice of an adequate response. In this case, as the action time decreases, so also does the reaction time to a signal. An essential variation of the parameters of a complex reaction can also be observed in the course of the annual training cycle. The content and organization of the work loads affect reaction time, so that, as the sports skills improve, there is a decrease in the time span necessary for the perception and re-elaboration of the data.

In combat sports and games, mental elaboration is an important element in the improvement of the execution time of a movement. For example, in ice hockey or soccer, the characteristics of an attacker’s movements in time and space, during the preparation for a shot, allow a high level goalkeeper to foresee the direction of an oncoming ball and, consequently, take the correct decision.

Examples of simple, isolated movements without overloads, requiring a high degree of movement quickness, are: a single blow in boxing, a thrust in fencing, a shot in hockey. These movements are accomplished with the active participation of the lower limb and trunk muscles. The co-ordination of these body segments is relatively simple and therefore does not affect the quickness of the movement itself.

When the movement entails a variation of body position in space, or the transition from one action to another, muscle co-ordination is more complex. An example could be when a boxer needs to change direction: stepping sideways, moving body and head in opposite directions, and changing from attack to defense.

In complex movements, execution time depends on a sound intra-muscular co-ordination. The nervous system’s state of arousal, reaction time and quickness of execution are closely connected to the degree of automatism, i.e. to how simple that movement is for the athlete. When the required co-ordination is complex or when a greater body mass is transferred, quickness depends on strength.

The speed of a movement with no overload has not, as yet, been investigated thoroughly, probably because the incidence of such movements in sport is not relevant. Examples are dribbling, the progression of the ball in basketball or hockey. There is a significant correlation, in regard to maximum speed, between movements having similar co-ordination characteristics, and an absence of correlation between movements having a different co-ordination structure. If we consider the functional anatomical structure of the human body, its maximum speed of movement is influenced by the fact that a higher rate can be achieved by the upper limbs as against the lower limbs and by the left-hand limbs as against the right-hand limbs. No correlation has been observed between the parameters of the rate of movement of the distal and proximal joints of the same limb. However, a slight correlation does exist between the parameters of movement of single distal joints (wrist joint and mortise joint and proximal joints, shoulder and hip]. The rate of a single movement with no overload, tapping for instance, is in no way correlated to an athlete's speed of movement or velocity in cyclic locomotion. It has been observed that the maximum rate of all movements involving a single joint has no correlation with maximum stride rate or a sprinter's running speed. Also no correlation has been found between the results of tapping tests and pedaling rate on a cycle— ergometer, with or without overloads, or the speed achieved in 150 and 200 meter runs.

Again, no correlation has been observed between the rate of a movement with no overload and other expressions of quickness, as, for instance in boxing, the maximum punch rate attained, the latent time and speed of execution of a single blow.

The rate of movement increases when symmetrical muscles are involved, or when the acoustic analyzer is stimulated. In boxing, the rate of movement has a direct connection with breathing rhythm and to the boxer's ability to control this rhythm. Another important factor that favors a high rate of movement is muscular relaxation.

Quickness, in all its specific facets, is influenced mainly by two factors: 1) the organization and functional regulation of the neuromotor apparatus and 2) the active and operative implementation of the motor structure of the movement. The first factor is strictly individual, i.e. connected to the genotype, and cannot be significantly improved. The second factor responds to training and provides the potential for the development of quickness. Quickness in a specific motor task is, therefore, positively influenced when the motor apparatus is adapted to the conditions in which the task is to be performed, and the athlete masters a sound motor co-ordination. The latter produces a complete exploitation of the individual characteristics of an athlete's central nervous system.

3 Movement and locomotion velocity

The concept of "quickness' in **a** simple motor task is totally different from the concept of "velocity" in the performance of sports movements. This statement is supported by the absence of correlation between the simple expressions of quickness and the velocity achieved in sports movements and cyclic locomotion. Velocity of this sort entails the mobilization of a group of physiological systems; it is based on the regulatory neurophysiological mechanisms and on the necessary metabolic processes. For example, a sprinter's performance depends on a number of motor abilities, such as explosive strength, initial acceleration capacity, the ability to maintain maximum speed over a given distance, endurance capacity in the last part of the race. Velocity in acyclic movements is determined by the muscles' capacity to overcome external resistance.

Sports movements and types of locomotion performed at great speed are characterized by the high degree of specificity of the physiological mechanisms involved. Despite some possible superficial similarity, movements performed at different velocities correspond to different work regimens in the body. For example, the main difference between a practice run performed at maximum or medium intensity, or a long jump performed with a complete or with a short run-up, lies in the intensity of the impulse current from the motor cortex of the brain, which determines the intensity of the work performed by the motor apparatus and, consequently, determines energy requirements.

However, while, for the central impulse current, it is simply a question of intensity; a qualitative difference arises in the peripheral impulses. The muscle fibers that are excited may be prevalently FT or ST, the spectrum of the hormone regulators aroused changes and different energy substrates are employed in different ways for ATP re-synthesis.

As movement and locomotion velocity increases, the regulatory mechanism varies. This entails quantitative and durational changes in the electrical activity of the muscle and in the afferent signaling of the motor apparatus. High velocity types of locomotion are performed without direct afferent signals (ballistic movements for example). The central nervous system determines their structure in space and their accuracy. In the case of high velocity cyclic types of locomotion, feedback is very important for the correction of successive movement cycles.

Research results show that an increase in velocity of a cyclic type of locomotion, for instance running, depends on the frequency of the cerebral cortex impulses directed to the motor neurons of the spinal cord. These impulses arouse and co-ordinate the skeletal muscles. At the same time, the motor cortex of the brain controls the flow of afferent signals providing information on the results achieved (feedback).

Energy production for high velocity locomotion is characterized by the speed and intensity of the mobilization of the energy in the muscle fibers; that is to say the speed of ATP breakdown when the nervous impulses arrive. The speed of contraction and relaxation of the muscles depends on myosin ATPase and on the fast action of the calcium pump which determines calcium-ion concentration in the myofibrillar inter-space of muscle cells. When high degrees of strength are required, movement velocity also depends on the contractile protein content of the muscle. When a movement is to be repeated several times at high velocity, a great potential of ATP anaerobic re-synthesis (creatine kinase, glycolysis) is required. Lastly, the duration of a high velocity task is determined by the possibility of ATP aerobic re-synthesis and by the body's energy potential, i.e. by the amount of glycogen reserves in muscles and liver.

An increase in "respiratory ATP re-synthesis" is very important in speed training. During the rest period, energy production for re-synthesis occurs through aerobic phosphorolysis, thus facilitating recovery for repetitions of the speed training exercises. This, in turn, allows an increase in the number of efficient high intensity exercises performed within a single training unit. For instance, when a sprinter runs 100 meters in 10.0sec, he does not require a high production of aerobic energy, but he does need an adequate aerobic capacity to achieve a fast recovery and, therefore, be capable of performing a number of repetitions during training.

Muscle relaxation is very important for high movement velocity. This is particularly true in cyclic types of locomotion, and is associated with ATP re-synthesis between muscle contractions. For this reason, muscle relaxation time varies considerably as the athlete's skill improves. It is interesting to note that, in some sprinters, improvement in performance is mainly the result of an increase in muscular strength, while muscular relaxation varies very little. On the other hand, talented sprinters show a very slight increase in strength and a greater increase in their capacity for muscular relaxation.

The adequate employment of muscle elasticity is an important requisite for efficient and economical high velocity cyclic and acyclic types of locomotion. This entails accumulating elastic energy during the preparation phase of a task and employing it fully for the execution of the task, through an increase in the strength of the motor impulse. In very economical, high velocity locomotion, up to 60% of the total mechanical energy can be recovered, and only about 40% is really spent in the movement cycle. This last quota will have to be replaced in the following cycle by metabolic energy sources. A high correlation has been observed between the muscle's capacity to accumulate energy and the performance of distance runners ($r = 0.785$) and, likewise, between performance and movement economy in running ($r = 0.780$). As the athlete's velocity increases, so the percentage of non-metabolic energy of the total of energy produced, also increases. Apart from increasing the intensity of the impulses sent to the muscles, which is important in itself, this allows the saving of a greater amount of metabolic energy.

Therefore, speed training produces global morphological and functional changes in the organism. However, the adaptive changes of the central nervous system, physiological and bio-chemical, develop much more slowly than do the capacities for strength and endurance. These changes can be maintained only for very brief periods of time.

In order to organize a rational training program, one must realize that adaptive changes induced by strength training and by speed training are very similar, and that the difference is essentially quantitative. In both cases there is an increase in muscle myoglobin and this indicates an adaptation to oxygen deficit. A relevant increase in myosin ATPase and Ca_2 consumption in the sarcoplasmic reticulum has been observed both for strength training and for speed training. This favours not only fast muscle contraction but also a greater development of tensile strength. Strength training induces a particularly significant increase in elastic myostromin, which allows better, faster muscle relaxation.

We can differentiate four specific high velocity work regimens:

- Acyclic work, characterized by a concentrated, isolated effort, followed by relatively long pause;
- Initial accelerations, in which speed is developed quickly, the aim being to achieve maximum speed in the shortest possible time;
- Distance work (speed endurance), in which high speed must be maintained for the time necessary to cover a given distance;
- Alternate work, which includes all the above regimens.

Acyclic movement velocity is determined mainly by the total muscular effort, rationally organized in time and space. In this case an increase in velocity may be obtained by increasing the force transferred to the body or the implement, thus shortening the time of execution of the movement (VERKHOSHANSKY 1961, 1970). This result may be obtained by improving the capacity of the motor cortex of the brain to dispatch intensive series of efferent impulses to the muscles, by increasing the potential of the body's functional systems and organizing their rational interaction, by intensifying the energy mechanisms and by creating a methodical bio-dynamic structure of the sports movement.

It should be noted that a high velocity in acyclic movements may be maintained for numerous repetitions, during training and in competition, only when the body's vegetative systems have a high functional level. For this reason, an increase in the degree of training of throwers is accompanied by greater economy of the circulatory system, achieved through an increase of the stroke volume and a decrease of the heart rate and of the peripheral resistance. It has been shown that the development of aerobic capacities is very important in the training process of weight-lifters.

Initial acceleration is a specific type of high velocity locomotion. It is characterized by the fast development of speed, from standstill to maximum speed. Examples are the start of a sprint race, a speed skating race and a rowing race, or a running kick in soccer and a tennis player's spurt to reach a lob. Since initial acceleration requires a high intensity effort, it must be produced by a high intensity current of arousal impulses from the central regulators to the peripheral motor system, and by high intensity work of the energy systems.

In sprinting, for instance, initial acceleration is determined by stride length (not stride rate). This is achieved through a high level of explosive and maximum strength of the muscles involved. Initial acceleration is a specific motor skill and it is not correlated to the rest of the sprint performance, because there are differences, not only in the nervous regulation of the movements, but also in the functional role of the muscles involved. Thus, the correlation between the speed-strength index of the thigh flexor muscles and the initial rate of acceleration is very significant, while the correlation between this same index and running speed in the rest of the race is not significant.

Initial rate of acceleration is determined by the body's maximum anaerobic power, which is expressed by the speed of energy generation per unit of time, in the anaerobic-alactacid process. There is a high correlation between maximum anaerobic power and maximum muscle strength, and it has been shown that high anaerobic power allows the organism to repeat initial accelerations efficiently, both during training and in competition. My laboratory colleagues observed that maximum anaerobic power (MAP), maximum muscular strength and the athlete's capacity to accomplish intense effort are closely connected. It appears, therefore, that maximum anaerobic power is best developed through specific strength training, organized according to the particular competition requirements. This statement is supported by the fact that bobsleighing coaches try to recruit throwers, jumpers and sprinters, because these athletes have high maximum anaerobic power and are capable of achieving high levels of explosive strength.

In cyclic locomotion, we can differentiate the three distances (sprints, middle distances, long distances) that correspond to different work intensities (respectively: maximum, sub-maximum, medium) and to different energy recruitment modalities. As stated earlier, the intensity of cyclic work is determined by the intensity of the impulse current from the motor cortex of the brain.

In high velocity types of locomotion, such as sprinting, the impulse current reaches maximum intensity. The motor apparatus produces high intensity work and activates the fast twitch and intermediate muscle fibers. Intense activity of the hormone system causes an increase in anaerobic ATP re-synthesis (phosphocreatine) and glycogenolysis, which produces lactic acid in the muscles involved and in the blood. The main sources of energy are phosphocreatine and muscle glycogen. In these types of locomotion, the speed limit is set by the capacity of the motor cortex to maintain maximum impulse intensity, the speed and potential of the metabolic reactions, the amount of phosphocreatine and glycogen reserves in the muscle fibers and the level of lactate concentration in the muscles.

In the case of locomotions at relatively lower velocities, the intensity of the impulse current to the spinal cord motor neurons and of the motor apparatus work is also lower. This type of work involves mainly slow twitch and intermediate muscle fibers and only a small part of fast twitch fibers. The metabolic and energy process regulators that are activated are responsible for homeostatic reactions, peripheral vas reactions and the subdivision of the blood flow between the body's active and inactive tissues. Depending on the intensity of the work, the energy substrates are glycogen and free fatty acids.

Work efficiency and the capacity to sustain prolonged effort are determined by oxygen transport, which, in turn, is determined by the volume of pulmonary ventilation and by the flow rate of the blood. The latter is related to heart rate and to systolic blood flow. Oxidation capacity of the slow twitch fibers is extremely important.

In cyclic sports, speed is basically determined by the correlation between movement rhythm and intensity of effort, i.e. stride rate and stride length. The average velocity of a cyclic movement (Vm) is expressed by the equation Vm = L x R; it is therefore a function of stride length (L) and stride rate (R) (DILLMAN 1975). However, the final result is determined by energy expenditure, which in turn depends on the relation between the rhythm and intensity of effort entailed in each movement cycle, i.e. stride length, economy and effort distribution over a given distance. In some forms of locomotion, swimming for instance, inertia is important as regards energy consumption. In track and field athletics, this factor does not exist; the specificity of the movement depends on the so-called "forward impulse" and on the vertical oscillation of the athlete's centre of gravity, which greatly influences energy consumption.

Observation shows that the stride length/rate ratios used vary greatly. Some believe that well trained athletes will automatically find the appropriate rate and length for minimum oxygen consumption. However, the issue of the relationship between the rate of movement and the amount of effort expended is so important that it is difficult to believe it can be so simple.

Different points of view can be found in the available literature on this subject. Discrepancies are mainly formal and are concerned with differences in the biomechanical characteristics of the various types of locomotion, the skill of the athlete and the aim of a particular author's research.

Specific research has established that a longer stride, a longer stroke in swimming and a longer gear ratio in cycling are more efficient in terms of energy consumption, due to the optimal rate of movement.

We should, therefore, consider these data and examine the issue of length/rate ratio carefully, in order to find an explanation for each of these examples. One possible way of finding the optimal length/rate ratio is by means of special conditioning work (VERKHOSHANSKY 1977) to develop local strength endurance in the muscles involved.

In cycling, studies have shown that an increase in the strength component of each pedal stroke is indeed efficient, in terms of an increase in speed and the distance covered with each rotation. For instance, high level road race cyclists who used higher resistances on the pedals during training achieved a performance improvement of 35.6sec over 25km. Cyclists whose training involved mainly high pedal stroke rate and little resistance improved only by 21.5sec. Energy consumption with a standard load decreased, respectively, by 7.9% and 5.7%, strength in the pedals' downward stroke increased by 8.3% and 56%, in the pedals' upward movement by 10.5% and 7.3% and the duration of exercise to exhaustion increased by 104.3% and 86.8%. No significant difference was observed in the increase of maximum oxygen consumption which was 8.7% and 8.4% respectively.

Therefore, when looking for a method to increase the velocity of cyclic locomotion, one should not immediately opt for optimal length / rate ratio. Higher velocity requires not only aerobic capacities but also a high level of strength. A runner who wishes to achieve a good performance must have a high level of explosive strength, in order to have a long, elastic running stride. He must also have considerable local strength / endurance, in order to maintain stride length over the entire distance and in the final spurt.

Training based solely on the economy of the driving phase and of energy consumption through an increase in stride frequency is not correct.

However, it is not always true that a longer stride is preferable. The length of the stride should always be related to the athlete's skill and to the particular phase of the annual training cycle. It may be observed that, as the work intensifies and the athlete's skill increases, speed in cyclic sports disciplines tends to increase at first because of a longer stride, but subsequently on account of a higher stride rate. This tendency is also an individual characteristic of the development of skill. If we consider the inefficiency, in terms of energy consumption, of a high rate of movement, any increase in velocity of cyclic locomotion must come, in the first instance, from an increase of stride length. Work to increase stride rate should be employed only in a subsequent phase of the training process.

The capacity to maintain speed over the entire distance is essential for the improvement of performance. During competition, especially during the final burst, it has been observed that athletes tend to decrease stride length, stride rate and movement velocity. The decrease in stride length occurs even earlier than the decrease in speed, as this can be maintained through an increase in stride rate (during the so-called “state of compensated fatigue” mentioned by FARFEL 1969). When the athlete cannot compensate for the decrease in stride length in this way, then speed decreases also and fatigue is no longer compensated. It has been observed that an athlete’s movement parameters are more stable about halfway through the race, at the onset of fatigue. At the beginning of the race and when fatigue level is high, variations in the movement parameters are higher. Therefore an increase in speed, stride length and stride rate at the beginning of the race may entail a decrease in the athlete’s work capacity and performance may deteriorate.

Movement velocity and performance in cyclic locomotion are determined mainly by the athlete’s efficient use of his or her motor potential — the economy of muscular activity — which is defined as energy value per unit of work. Experts assert that, in sporting activities, we have already reached the maximum level of aerobic and anaerobic productivity, the threshold of the human body’s possibilities. Therefore, improvement in sports performances must come from the more efficient use of the athlete’s energy potential. This is confirmed by the fact that, with a given load, a well trained athlete will expend less energy than a less well trained athlete. A more economical expenditure of energy may be achieved by improving movement co-ordination and technique. Functional economy is verified by the parameters of the activity of the muscles involved in running at competition speed. For instance, it has been observed that, compared to beginners, high level runners have shorter contraction times and longer relaxation times. High level speed ice-skaters can be recognized by a lower value of total muscular activity in all phases apart from the leg drive, during which the electric activity of the muscles is more efficient by 45% than that of less qualified skaters. The movements of high level skaters are therefore marked with a high degree of economy, which is expressed as a lower O_2-pulse per meter covered.

Energy economy is also determined by the increased efficiency of the metabolic processes, which produce a reduction in energy consumption per unit of work. Effort distribution over a specific distance is also important for the economy of energy output and performance. This is due to the greater economy in energy consumption that may be achieved when working in the so-called steady state, where the speed at which ATP is formed through oxidative phophorolysis is equal to the speed at which it is broken down, and the required energy is supplied by the oxidation of carbohydrates or fats. In other words, the steady state is maintained up to the limit of the anaerobic threshold, after which it becomes necessary to employ anaerobic energy supplies. Therefore, an athlete with a high anaerobic threshold may achieve and maintain a high speed, without causing the build-up of anaerobic metabolism products.

It is not always possible to maintain a regular pace over the entire distance. Some circumstances require a variation in speed; the athlete may have to fight for a favorable position before the finishing spurt, or a favorable position in terms of aerodynamics or for other tactical reasons. During a race the aim should be to maintain a regular pace over the entire distance, but the runner should always have extra power in store to face possible rhythm and speed variations.

The specific speed depends on a variety of factors, but the best way to improve speed is to increase the percentage use of the aerobic energy supply. This can be achieved, not only through an increase of the maximum oxygen uptake (the traditional method), but also through the use of specific training methods to develop the oxidative capacity of the muscles.

Many sports disciplines are characterized by alternate spells of fast and slower work (games, combat sports) — many efforts of maximum explosive strength are alternated with short intervals of low intensity work, while maintaining accuracy and efficiency of movement. Intensive work loads, together with variations in movement co-ordination and rhythm, induce functional changes in the cardiovascular, nervous and respiratory systems. High psychological tension causes a deterioration of the physiological, biochemical and psychological functions, with a resulting negative influence on movement velocity and technique (co-ordination).

Energy supply (ATP re-synthesis mechanism) in this type of work comes from creatine phosphate and from the break-down of glycogen and glucose. The aerobic mechanism plays an important role in energy supply, as it determines the speed at which the oxygen deficit is contracted and then cancelled. Therefore, sports activities requiring an alternate work regimen depend on the intensive use of both the anaerobic and the aerobic mechanisms. Athletes with a high work capacity, therefore, have an exceptional economy in oxygen consumption and blood flow rate. This provides stable respiratory parameters and thus influences the efficiency of the energy supply and recovery.

Therefore, the specific characteristics of the regulatory mechanisms and of energy supply in high velocity locomotion are also fully involved in alternate high velocity work. At the same time, each discipline has its own particular characteristics of movement velocity, which are associated with the specificity of the discipline, its rules and the competition conditions. The requirements of a particular locomotion velocity depend on various factors: the total duration of the game, the duration of specific phases of the game, the duration of the breaks, the size of the playing field, the characteristics of the body's work regimen, the relationship between active and passive actions and the possibilities of recovering during the game. Therefore, if the special work capacity is determined by the potential aerobic I (energy supply) mechanism, the speed of execution of technical and tactical actions depends on the factors outlined in Table 1.

Table 1: Determining factors of the performance velocity of technical and tactical actions in different sports

Sports Discipline	Capacity
Volleyball	strength endurance (particularly for the jumps)
Tennis	explosive strength; maximum anaerobic power
Wrestling	maximum strength and explosive strength; strength endurance and speed strength endurance
Games (on large playing fields)	strength endurance; explosive strength; maximum anaerobic power
Fencing	reaction time; static endurance; dynamic endurance
Boxing	rate endurance; speed endurance; explosive strength endurance

Each sports discipline has its own functional structure of muscular activity, which includes the body's physiological systems associated with an intensive work regimen.

The creatine-phosphate mechanism plays a very significant role in movement velocity (locomotion). In the case of an alternate work regimen, energy supply also requires the activation of the glycolytic mechanism. Therefore, despite pauses in activity and a very efficient recovery process, there is a gradual increase of lactate concentration in the blood.

Therefore, to maintain high velocities over a given distance, in the conditions peculiar to an alternate work regimen, the athlete's training should be concerned not only with the improvement of the cardiovascular system, but also with the adaptation of the muscular system to oxygen consumption and to the aerobic metabolism. The latter induces a percentage decrease in the activation of the glycolytic energy supply and may be achieved through specific training.

We shall now return to the concepts of velocity and 'quickness", in order to identify a training methodology.

1) Velocity and quickness show a significant correlation when there is slight external resistance, when the movement is simple and when intensity and duration are low. Otherwise, the correlation between velocity and quickness is not significant.

2) The determining and limiting factors of speed and of quickness are different. Their development, therefore, requires different means and methods.

3) There is no limit to the development of movement velocity (locomotion), as opposed to quickness. The limit to the development of quickness is set by the athlete's individual characteristics, i.e. his genotype. On the other hand, the development of velocity is practically limitless, because the development of strength and of endurance, as well as the improvement of co-ordination, is unlimited.

Quickness and velocity are two separate characteristics of human motor skills. Quickness is a general quality of the central nervous system and is fully expressed in motor reactions and in simple motions with no overload.
The quickness characteristics of an individual are genetically predetermined, and, therefore, there is little space for improvement. Movement velocity (locomotion) is a specific human motor skill which may be improved by means of special training.

Scientific literature contains a number of concepts concerning human motor abilities (strength, speed, endurance), which helped us, in the past, to classify training means and construct a training plan. However, these criteria, intended merely to be a qualitative evaluation of motor skills were considered as the sum of all mankind's physical qualities. The prevailing opinion was that each quality was regulated by its particular physiological mechanism. The logical conclusion was that an athlete's physical preparation had to be synthetic, i.e. each quality had to be developed separately and then merged with the others. Unfortunately, physiology and biochemistry accepted such a simplified approach and encouraged this diffusion of an analytical-synthetic approach to training. Nowadays, experiences in the field and the more advanced scientific investigations indicate that the traditional concepts of training theory and methodology are no longer viable.

It must be emphasized that, in all types of activity, work is effected always by the same organs and controlled by the same regulatory centers. All functional systems of the body are involved. Evolution has not provided mankind with strictly specific mechanisms to perform each type of movement. It has provided us instead with a universal system, which has great functional possibilities and outstanding reserves in terms of the resistance to external forces — the capacity to adapt to external conditions through a hypertrophy of the systems and organs involved.

Therefore, there is no specific mechanism that is solely responsible for speed, for strength or for endurance. Every type of sporting activity uses the same functional systems. However, during the training process, these systems may acquire a specialization, depending upon the specific type of work required by the sport concerned. An increase in the capacity for work does not depend on the development of specific qualities, but on the body's specialization in a specific direction, strength, speed, endurance.
This conclusion indicates that a change is needed in the methodology of training, especially in regard to physical conditioning.