THE RELATIONSHIP BETWEEN REACTION TIME AND SPEED OF MOVEMENT

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ABSTRACT

Helmi Hussein Mahmoud. "The Relationship between Reaction Time and Speed of Movement".

The ability to move the body or its limbs quickly is a complex function, involving neuromotor lactency as well as the net motor component of the movement. The question of the degree of relationship between individual differences in the speed of reaction and the actual speed of movement of the body or a limb was implicitly raised in 1937. From that time on the research findings were contradicted, with the most of the published research said that the functions of speed of reaction and speed of movement are independent and show that these phenomena are unrelated, whereas some other research does not concur and provide evidence of a positive significant relationship.

The purpose of this paper was:

1. To summerize some of the research work in this area which may help in further investigations.
2. To elucidate the mechanisms underlying the neuromuscular function in the reaction to any information; the nerve impulse; the transmission of excitation from nerve to muscle; the muscle action potential and excitation.
3. To summerize the conclusions and principles which are of potential interest and help to the physical educators and athletic coaches from the research findings.

«العلاقة بين زمن رد الفعل وسرعة الحركة»

تلخيص

تعتبر المقدرة على سرعة تحريك الفرد لجسمه أو أي عضو من أعضاءه المختلفة عملية معقدة تحتاج إلى تعاون عمل الجهازين العضلي والعصبي معاً حتى تتم الحركة .

وقد أثير : التساؤل عن مدى العلاقة بين زمن رد الفعل والسرعة التي يتحرك بها الجسم أو أي عضو منه لأول مرة عام ١٩٣٧م . ومنذ ذلك الحين تضاربت نتائج الأبحاث العلمية . فقد استنتج اكثرها أن زمن رد الفعل عنصر حركي مستقل وقائم بذاته ومكون منفصل عن سرعة الحركة التي تليه وان كل منهما يعتبر عنصراً منفرداً يحتاج إلى تدريب خاص لتنميته ، بينما عرضت بعض الأبحاث تلك النتائج واثبتت بأن هناك ارتباط ايجابي عالي بين كل منهما ومازالت الاجابة الحاسمة عن مدى الارتباط بين سرعة رد الفعل وسرعة الحركة في المجال الرياضي في حاجة إلى مزيد من البحوث . أما الغرض من هذا البحث فيتلخص فيما يلي :

* جمع وتلخيص عدد من البحوث في ذلك المجال لتكون عونا لمن يريد المساهمة بمزيد من البحث .
* القاء الضوء على ميكانيكية عمل الجهازين العضلي والعصبي منذ الاستجابة للمؤثرات الخارجية ونقل الاشارات العصبية إلى العضلات حتى تقوم بالعمل الحركي .
* تلخيص : الاستنتجات والمباديء التي تهم وتفيد مدرس التربية الرياضية والمدربون في المجال الرياضي من نتائج الأبحاث التي تمت .

INTRODUCTION

A great deal has been said in recent years about human movement and the closely related factors which influence it. Human movement is inevitable as man's changing life processes interact with and react to his dynamic and constantly changing environment. Through sports, exercise — the individual overcomes both his own force and the forces of the universe. Movement is associated with muscular contraction and all motor performance involves muscle action in its myriad forms. It is also associated with neural mechanisms; hence psychomotor or sometimes neuromotor or neuromuscular. There are levels of utilization of body's forces. There are many restrictions or limitations on movements some of which are variable and change as man's experience changes.

Human movement is a complex quality and is influenced by many forces:

First, physical performance factors which underlie the action for all movement. These factors include speed, agility, endurance, strength, power, etc. and are revealed through the fundamental skills of running, jumping, throwing, climbing, hanging, etc.

Second, structural factors which either help or hinder movement. These factors include age, height, weight, body type, and structure.

Third, sociopsychological factors which influence behaviour and ultimately affect movement to a marked degree.

The physical educator generally measures the first of these when he is interested in evaluating movements, although indirectly he may concern himself with the second if he establishes norms for those movements based on age, weight or height, or combinations. The coach and teacher must also be cognizant of third group consisting of certain mental, emotional and social factors. These do have great influence on movement. The physical performance factors are the ones most influential in this area. They are of three kinds:

1. Basic factors to all performance, such as agility, power, speed, arm and shoulder coordination, balance, flexibility, etc.

2. Fundamental movements, such as running, jumping, throwing, climbing and hanging. These are called racial activities and are common to the performance of all people since they make up the basic patterns of motor movement.

3. Highly specialized movements which are the result of training and experience and which are not common to all individuals. These are acquired through practice and specialization. They include athletic or sport activities and skills, gymnastics and dance. These highly specialized movements represent the result or the influence of the factors which are basic to all performance and also the fundamental movements. The fundamental skills are both cause and effect since they are the result of the basic factors and are themselves basic to the specific sport skills. The factors which are basic to all motor performance are causal and represent the first level of performance.

In addition to these, there are the processes of perception which now appear to be inexorably related to movement. That was a general introduction (12:119) about different types of movements and from that we are concerning here with the ability to react and move quickly and elucidate the relationship between the reaction time and movement time and their importance in sports.

In today's modern technological society with its emphasis on sophisticated equipments, rapid transit and space travel there has been an increased demand for man to react quickly to stimuli and make a great variety of responses (24). The need for speed of movement seems obvious in sports games (basketball, tennis, soccer, etc.). The short sprints in tract meets illustrate most vividly the contribution of pure speed of movement to successful performance. Further examination of athletic games reveals many situations calling for split second responses. The successful discharge of maneuver depends not only on how fast it is performed, but also on speed with which the movement is initiated. Baseball games, soccer, and track meets hold many obvious illustrations of importance of reaction time as well as movement speed. The sprint start and movement of the shortstop to field a hard hit ball are examples of situations where the time taken to react would be very important to the successful accomplishment of the task at hand (5).

An athlete is said to possess fast reactions, for example, when in truth he is able to move quickly and accurately in a highly skilled act. Few realize that within the scientifically correct definition of the term reaction time the athlete does not move! Defined "scientifically", reaction time is: the time between the stimulus (a starter's gun, the movement of the ball starting a play in football) and his first movement in reaction to the stimulus. A correct definition of movement speed is: the time after the initial reaction time has been completed including the time the observable movement takes place and terminating with the stopping of the movement (3:32(.

REVIEW OF LITERATURE

The ability to move the body or its limbs quickly is a complex function, involving neuromotor latency as well as the net motor component of the movement. The question of the degree of relationship between individual differences in the speed of reaction (latency between signal and start of movement) and the actual speed of movement of the body or a limb (timed from start of movement to its end) was implicitly raised by Rarick, L. in 1937. (31) This question was again raised by Henry, F.M. in a report published in 1952. Henry found that the functions of speed or reaction and speed of movement are independent. Later studies by Henry, Slater, Hammel, show that these phenomena are unrelated, whereas the research of Pirson, Barry and others provides evidence of a positive significant relationship.

An early study by Westerland and Tuttle found a significant correlation between RT and MT in sprinting a distance of 75 yards. Later studies conducted by Slater Hammel and Fairdough using different movements, reported nonsignificant correlations; sunsequent research by Pirson and Cooper has supported these results. However, two studies by Youngen and Pirson which employed similar movements and apparatus, reported positive significant correlations between RT and MT.

Findings of nonsignificant relationship between RT and MT were subsequently reported by Hodgkins (14), Henry et.at. (8), Philip J. et. al. (22), Willard (31), Stephen (27), Leon (17). However a recent study by Barry (2) has once again thrown doubt on the whole question of the correlation between RT and MT. As the result of these findings, we can see that most of the published research in the area of the relationship between reaction time and movement time said that there was no significant relationship between them and some other research, does not concur. So, I believe that the area of a relationship between the ability to react quickly and to move quickly is once again open to more investigation.

SUMMARY OF SOME RESEARCHES IN THE AREA OF REACTION AND MOVEMENT TIME

Researcher(s) & year	Purpose of Research	Measurement Apparatus	Subjects	Results
Thomas P. Colgate (29) 1967	Add to the knowledge of reaction time comparing the variation in reaction and response times of individuals subjected to visual, auditory, and tactile stimuli when the subjects did not know which stimulus they would receive.	1. Response unit to measure the speed to reaction and the speed of response 2. Stimulus unit 3. The recording unit 4. The control unit	50 male students · from PE skills classes at the State U. of Iowa	1. Speed of Reaction A. Auditory stimulus favor visual stimulus (P=0.001) b. Auditor stimulus favor tactile stimulus (P=0.001) c. Visual stimulus favor tactile (P=0.001) 2. Speed of Response a. Auditory stimulus favor visual stimulus (P=0.001) b. Visual stimululus favor electroshock stimulus (P=0.001) c. Auditory stimulus favor electroshock stimulus (P=0.001) 3. For both speed of reaction and speed of response

				a. The group means were lower when the subject responded to the auditory stimulus than when he responded to the visual or electroshock stimulus b. Speed of reaction and speed of response were faster when subjects responded to the visual stimulus than when they responded to electroshock stimulus.
Robert W. Christian (26) 1973	To test the prediction that enforced motor set results in longer reaction & movement times than does enforced sensory set (concentrating on the stimulus) & to determine the effects of enforced motor and sensory sets on reaction & movement time based on "memory drum" theory	1. Four response keys 2. Four clocks 3. Two hunter .001 sec clock counters	30 right handed male under graduate & PE majors at State U. College at Brock Portage	1. Mean variate lower than mean covariate times for both groups. 2. Mean variate RT was greater for motor than for sensory set 3. Mean MT less for motor than for sensory set 4. The ANCOVA revealed that the contrast between sets for RT was significant whereas the contrast between sets for MT was not significant. 5. Enforced motor results in longer than does enforced sensory set. 6. The MT could not interfere with the nonconcious operating functions.
Mary Lou Norrie (19) 1974.	Know the effect of movement complexity on simple reaction time	A box 19.5" long, wide, & 3" height was placed on a 30" high table	48 college age men from activities classes	1. For the simple movement choice RT tasks the decision process occurred before the start of movement. 2. For the complex move-

	& movement time			ment choice reaction time tasks most of the decision process occurred before the start of the movement. 3. Under choice reaction conditions movement time tend to increase somewhat for the complex movement condition but not for the simple movement condition. 4. As the number of choices increased the effect of increasing movement complexity on RT lessened.
Jean Hodgkins (14) 1962	1. To compare males with females in speed of reaction & movement 2. To ascertain whether or not a relationship exists between RT & MT	Telegrapher's key, 2 110 volt A.C. 1/100 sec. chronoscopes, a terminating rod, a photoelectric unit & a visual stimulus light bulb.	930 men, women and children age from 6 to 84.	1. Males are faster than females in both reaction & movement. 2. Speed of both functions increases up to early adulthood and then decreases. 3. Peak speed is maintained longer by male in movement and longer in females in reaction. 4. In the majority groups studied no relationships exists between speed or reaction and speed of movement.
Franklin M. Henry & Donald E. Rogers (9) 1960	To test the hypothesis 1. The simple RT required for the initiation of movement that vary from simple to complex 2. Age & sex differences in RT and MT.	1. A reaction key 2. 2 tennis balls each hung by a string 3. An electric gong	1. Group 1 30 males 2. Group 2 30 females 3. Group 3 20 young men age 19-35 years. 4. Group 4 20 eighth grade boys age 11-12 5. Group 5 20 fourth grade	1. Under controlled conditions, simple reaction time becomes longer when the type of movement which follows the reaction is varied from very simple to relatively complex, further in crease incomplexity produces additional slowing but to a lessened degree. 2. College women have less arm speed ability than college men

			boys ages 8-9	3. 8 year old boys have less arm speed ability than 12 year old boys. 4. Individual differences in speed of movement ability are predominantly specific to the type of movement that is measured there is only a relatively small amount of general ability move the arm rapidly
Franklin M. Henry and Willard S. Lotter, and Leon E. Smith (11) 1961	1. Factor analysis of reaction time & maximal limb speed 2. Measurements of RT, speed, strength & the ratio of limb strength to limb mass.	Balls for throwing & kicking Bicycle	80 college men in experiment 1 & 70 college men in experiment 2	1. The correlation between the RT and MT is approximatel zero. 2. There is a fact of quickness of limb reaction. 3. There is a fact of limb speed that is unrelated to the reaction factor. 4. Limb speeds for single discrete movements and for continued cyclic movements are included the same limb speed factor. 5. There is a fact of ratio of strength to limb mass that unrelated to the limb speed factor. 6. There is is a fact of limb strength as such, that has a common element of body size.
Philip J. Rasch and William R. Pierson (22) 1962	Reaction & movement time of experienced. Karateka	Consist of: A stimulus lamp with a chronoscope A microswitch A photoelectric beam	12 experienced Karateka and 32 AAU	There was no significant differences in either the reaction or movement times of the two groups.

Stuart Levit and Bernard Gutin (28) 1981	1. To examine multiple choice RT performance while subjects were walking on a treadmill at HR 80, 115, 175, beats/min 2. To determine the relationship between EIA & MT	A motor driven treadmill. Five red lights in semicircle with a radius of 6 in. A button.	20 males under graduate at Brooklyn College	1. Reaction time optimal performance was demonstrated a HR of 115 6 pm. 2. Movement time As EIA increased, MT decreased in a linear manner. 3. It appears that five choice RT & MT are affected quite dirrerently by EIA
A.T. Slater Hammel (1) 1960	To obtain further information on the reliability, accuracy & refractoriness of transit reaction	A visual display, an electronic chronoscipe, a Hunter-Brown interval timer & a signal key. A model SW-1 standard electric clock. Two 22×28" panels.	19 males & 6 females from Indiana U. age from 19-62 years for the first experiment & 10 males students for the second experiment.	1. Reliability coefficients were high. 2. Knowledge of results had no marked effect upon constant errors, had pronounced effect upon the accumulation of absolute errors. The error for performance with knowledge of results was smaller than performance without knowledge. 3. The error for performance with knowledge of results and no catch trials was smaller than for performance with knowledge of results and catch trials. 4. The introduction of catch trials had a pronounced effect upon constant error. 5. The measured threshhold refractory period was found to be 14m/sec allowing for positve systematic bias in transit reaction increased the estimated threshold to 166 m/sec.

William R. Pierson (3) 1958	To investigate the extent of the relationship of movement time & reaction time from childhood to senility.	The apparatus of Pierson was modified to include an addition chronoscope in order to terminate MT, by interruption of a light beam to a photoelectric cell.	400 males age from 8-83.	For males between ages of 8 and 83 there is a statistically significant correlation between reaction time and movement time.
Carlton R. Meyers et. al, (4) 1969	The effect of benchstepping in the Harvard step test upon finger and foot RT	Bench, 20 inch height Athletic performance analyzer (Dekan Timing Devices, Glen Ellyn)	116 males	The findings failed to divulge any discernible effect of stepping exercise upon RT or any apparent relationship between RT and the sum of the recovery pull counts following the exercise.
Oois Youngen (18) 1959	To compare the RT and arm MT of selected women athletes with women non-athletes.	The apparatus was consisted of a response unit, recording unit & stimulus producing unit which was a modification of that used by Pierson in his study of fencers.	47 women athletes and 75 women non-athletes.	1. Women athletes faster then women non-athletes in speed arm movement and retion time. 2. Neither RT nor MT is correlated with each assigned ability positions in tennis, swimming, fencing or field hockey. 3. Within the athlete group: A. Tennis players, swimmers, fencers & field hockey player not differ in RT. B. A trend indicate that the swimmers are the slowest movers, difference was between field hockey, fencing and tennis. 4. MT and RT of non-athletes taking course in tennis, swimming, fencing are unrelated to PE achievement.

				5. A statistically significant but low correlation exists between RT and MT among athletes and nonathletes
Willard S. Lotter (31) 1961	Inter-relationship among reaction times & speeds of movement in different	Chronscope circuit Stimulus signal (a neon light)	105 college men in two groups	1. Leg movements are slower and have a lower RT than arm movements 2. There is more specificity and less generality of individual differences in MT than in RT & more specificity
	limbs			between arms and legs than between the two arms or the two legs. 3. There is more specificity between diagonoally paired arms and legs than between arms and legs on the same side of the body. 4. RT and MT are distinctly different and unrelated abilities 5. Individual difference in the movements are specific to the limbs used only.
Stephen Mendryk (27) 1959	Reinvestigate the relationship between RT and MT for the 11 in. forward arm thrust movement employed by Pierson.	Horizontal panel 7½ × 13 inches. Reaction key. A light weight celluloid target 2×3×.035 in. A warming light and a signal light.	150 sybjects divided into 3 age groups. 50 subjects each, having normal mean ages of 12, 22, 48 years.	1. Junior high school age boys as well as middle as middle-aged men are slower than college age men in RT and MT. 2. RT ability and MT ability are uncorrelated. 3. There is more task specificity than general speed ability among individual differences in speed of movement.

Franklin M. Henry (10) 1960	Test the hypothesis that adoption of the motor set results in slower RT than is the case with sensory set. Whether individuals tend spontaneously to adopt a sensory or a motor set, or perhaps vacillate or even have no clear set.	A modification apparatus in it. Visual warning signal. Reaction stinulus. Electric gong. Reaction key. Tennis ball suspended 30 cm. Chronoscope.	40 men 40 women.	1. Adoption of the motor set slows RT and MT. Both RT and MT average slower when subjects are required to use the motor set than in the case when they are required to use the sensory set. 2. There are individual differences in natural tendency to use the sensory set or the motor set. 3. Individuals who have a natural tendency to use the motor set tend to ract somewhat faster and they move considerably faster when using the motor set.
	Sex differences in the influences of these factors.			4. College women react slower and have a slower speed of arm movement than college men, their natural set tendency is more sensory than the almost natural set tendency of men.
Leon. E. Smith (17) 1964	The measurement of RT & MT when the suported limb was subjected to conditions of muscular stretch, relaxation & tension.	Semicircular platform. Rectangular pieces of copper plate. Nine microswitches.	40 college men.	1. Under the condition of stretch, the maximum velocity of an arm movement was not significantly faster than when the arm was tensed or relaxed. 2. During the state of tension the subjects produced a 4% faster MT and 7% faster RT than compared to when the arm was in a more relaxed position. 3. For both RT and MT the fastest speeds recorded for the 3 experimental conditions were stretch — tension — relaxation.

				4. Correlations between reaction time and movement time were insignificant during the conditions of relaxation, tension and streth.
Franklin M. Henry (8) 1952	1. The basic degree of relation or absence of relation between individual differences in RT and MT 2. The role of sensory stimuli that function to improve speed of action when administered to the subject during the slower half of his successive response to a reaction signal.	Reaction key. Treadle and ball. Chronoscopes. Motivating stimuli.	60 Ss in the ball snatch without motivating stimuli and 43 Ss in the treadle test.	1. No correlation between RT and MT. They are considered as independent and unrelated 2. MT was somewhat less influenced than RT by the motivation, but the statistical evidence did not clearly prove the point. 3. The improvement is due to the information value of the motivating stimuli rather than punishment as such, to a direct facilitation function.
Barry A. Kerr (2) 1966	To determine the relationship between the ability to react quickly and the ability to move quickly using the knee extension movement of the leg.	Consist of Reation key. Honey well standard microswitch. Light stimulus. Chronscope. Texas H-35 photoconductive cell. Two GENE 45 three watt neon bulbs.	47 males age from 18-23 years.	Speed of reaction and speed of movement were correlated.

Joseph E. Hipple (15) 1954	To test the hypothesis that an increase in speed of RT and/or MT due to informational motivation is accompanied by a rise in muscular tension. To discover any racial differences in RT and MT.	Electrical sound source attached to the reaction apparatus. Reaction key. Chronographs. Light weight rubber tube. Pheumatic bulb.	30 Negro, 30 white boys, age 12-14 years.	1. No racial differences before motivation in RT and MT. 2. White boys improved 8% in RT and 18% in MT, Negro boys 5% in RT and MT (compared with control groups). 3. Improvement in Negro speed was extremely variable and not significant. It was negatively correlated with change in tension. 4. Improvement in white speed was significant and positive correlated with tension. 5. RT and MT showed low intercorrelations
Richard H. Fairclough (25) 1952	To determine whether motivated improvement in movement of one part of the body transfers to cause improvement in movement of some other parts of the body.	Modified apparatus.	44 Ss age from 17-26.	1. Improvement in MT in one part of the body can transfer to cause improvement in speed of different type of movement in some other parts of the body. 2. RT showed a larger and more significant transfer than MT. 3. No difference between sound and clock in causing RT improvement either in direct motivation on the hand or in transferred motivation to the foot. 4. There was no intercorrelation between RT and MT or between transferred improvement in reaction and movement.
Maxwell L. Howell (20) 1953	To know the influence of emotional tension on speed of	Modified apparatus plus two tennis balls electric clock, two	50 male students age from 17-30 years.	1. There was difference between the two groups in mean improvement owing to motivation in the knowledge series, with

	reaction and movement.	chrono-scopes, stimulus light, reaction key.		respect to the complete motor response. 2. A negative correlation between RT and MT. 3. There were no differences between the two groups in changes caused by emotional tension in any of the physiological measures except pulse rate and skin resistance. 4. The members of the tension group improved more because they were more highly motivated.

Elucidation of the Neuromuscular function in the reaction to any information.

The central nervous system (CNS) receives information about the outside world via exteroceptors reacting to light, sound, touch, temperature or chemical agents, and interoceptors stimulated by changes within the body. The CNS is equipped to receive, interpret, and handle information, and then to transform the result into muscular movements (23-37). So, if a stimuli activates a sense organ, its excitement will transmit through neural impulses to pass along afferent neurons, through the central nervous system, and down different neurons for the response organ to initiate its reaction (1).

The central nervous system is made up of two types of cells, neurons and glia. The neurons (nerve cells) have as their most obvious functions the receipt of messages (nerve impulses) from other neurons and the transmission of these messages to still other neurons or to muscle or gland cells. The glia, long regarded as functionally inert supporting cells. Neurons have other activities in addition to the transmission of nerve impulses, such as the storage and retrieval of memory traces and the processes involved in abstract reasoning. A neuron has a cell body, which contains the nucleus and a number of branching processes extending from the cell body. These are of two types: the dendrites, which receive incoming nerve impulses, and the single axon which transmits the nerve impulse to the next cell in the chain. Excitation is transmitted from one neuron to another across a junctional structure, the synapse, and from a motor nerve fiber to a skiletal muscle fiber across another type of junctional structure, the motor endplate.

A single neuron usually receives excitation from numerous other neurons and, through the terminal branches of its axon, it in turn excites more than one neuron downstream. In like manner, a single nerve fiber (axon) from a motor nerve cell in the brain stem or spinal cord breaks up into many branches when it reaches a skeletal muscle, and each branch supplies a single muscle fiber. A motor neuron and the group of muscle fibers supplied by the terminal branches of its axon constitute a motor unit, which is the functional unit of neuromuscular activity.

The nerve impulse

The membrane surrounding the neuron and its processes is polarized, that is, it possesses as electrical charge; the outer surface of the membrane is positive and the inner surface negative. (This results from certain proper of the membrane itself). Sodium ions, which are abundant in the blood and extra cellular fluid, diffuse through the membrane of the neuron rather slowly and are promptly pumped out again by the so-called sodium pump. (This is an energy-requiring process.) The major positive ion (cation) inside the neuron is potassium. Potassium ions tend to leak out of the neuron, but they are restrained from leaving it completely because they are attached by the negatively charged protein anions, which are too large to diffuse out of the neuron. Since sodium is effectively excluded from the neuron by the sodium pump, the slight net passive movement of potassium ions from inside to outside leaves the interior of the neuron relatively negative with respect to its outer surface. This difference in potential amounting to about 70 millivolts, is referred to as the resting memorane potential, and the nerve impulse is essentially a transient reversal of the polarity of the membrane. When a nerve fiber is excited, either by an electrical stimulus in the laboratory or by a nerve impulse in the body, there is a sudden increase in the permeability of the membrane to sodium ions. The inrush of positive ions momentarily reverses the polarity of the membrane, causing a local electrical current to flow between this region of the membrane and the adjacent region, which is still normally polarized. This result in reversal of the polarity at this site, setting up another local current flow. The series of local current flows in propagated down the nerve fiber as the nerve impulse or nerve action potential. The reversal of polarity at any one site on the membrane is of very brief duration; the sodium ions are pumped out again very quickly and the normal polarity is reestablished. The nerve fiber is now ready to conduct another nerve impulse.

Transmission of excitation from nerve to muscle.

The transmission of excitation from one neuron to another across a synapse and from a nerve fiber to any muscle fiber across a neuromuscular junction involves a common mechanism. In each case, the prejunctional nervė endings contain munute vesicles filled with a chemical transmitter substance, acetylcholine. The arrival of a nerve impulse causes the rupture of some of these vesicles and release of the acetychloline, which diffuses across the gap and stimulates the postjunctional membrane of the nerve cell or muscle fiber. The result is a wave of excitation that is conducted along the membrane of the nerve or muscle fiber.

The muscle action potential and excitation

The membrane of the individual muscle fiber is polarized in the same manner as the membrane of the nerve fiber, and the wave of excitation that spreads along the muscle fiber membrane has the same characteristics as the nerve impulse. In the region of the Z line of the muscle fiber, the excitation is transmitted to a system of membranes called the transverse tubules, which penetrate into the muscle fiber. The excitation spreads from the transverse tubules to another system of membranes, called the sacroplasmic reticulum. This causes a release of calcium ion, which initiates the contraction of the muscle fiber. The membranes of the sarcoplasmic reticulum bind large amounts of calcium, some of which is released just prior to the contraction of muscle fiber and is bound again when the muscle relaxes. This suggests that the wave of excitation conducted along the membrane of the muscle fiber in some manner triggers the release of calcium from the membranes of the sarcoplasmic reticulum, and that this calcium, in turn, initiates the contraction of the muscle fiber (according to the sliding filament theory the acting filaments slide between the stationary myosin filaments, thus produce actomyosin which works as an enzyme name actomys on ATP — P and high energy compound initiates the contraction of the muscle fiber. This process has a very important role in the speed of movement, the more ability you have to initiate your muscles, the more speed you will have). The action of calcium is indirect; it has been demonstrated that in a relaxed muscle a protein known as troponin prevents the interaction of actin and myosin. When calcium is released from the sarcoplasmic reticulum it bends to the troponin, thereby abolishing its restraining action on the contractile mechanism and the fiber contracts. Relaxation is initiated by the rebinding of the calcium to the membranes of the sarcoplasmic reticulum. The release of calcium in response to the arrival of a wave of excitation conducted along the sarcoplasmic reticulum, is probably related to the changes in electrical potential across the membrane. The reversal of this potential change in like manner probably leads to the rebinding of the calcium to the sarcoplasmic reticulum. This in turn, restores the inhibitory effect of the troponin on the contractile mechanism, and brings on relaxation of the muscle fiber (21: 21).

Schematic illustration of some of the connections within the central nervous system essential for coordinated muscular contractions:

The spinal motoneurons and interneurons are exposed to excitatory (+) as well as inhibitory (−) impulses from various levels of the CNS. The μ and $\propto$ systems are, in a eay, independent of each other, but are normally linked together via the interneurons. The afferent fibers come from muscle spindle, Golgi tendon organs, joint receptors and cutaneous receptors. They consittute feed back channels used in the integration of motor activity (23: 64).

Conclusions and principles for coaching

Research findings relating to reaction time and movement speed that are of potential interest and help to the coach include the following:

1. Generally, reaction time and movement speed are not highly related in the same group of athletes. That is, an athlete may or may not initiate a movement rapidly, but that fact tells us nothing about how fast he will move after the movement is initiated.

2. The most important part of most sports skills is movement speed, not reaction time. Thus primary emphasis in teaching a sports skill should be on attempting to get the athlete to move as rapidaly as possible (near competitive speed). A small percentage of his total efforts should be based upon how fast he initiates the movement.

3. In certain sports activities, however (sprinting startts, jump balls in basketball, the beginning of a football play or when a ball is intercepted) reaction time is critical, and steps should be taken to reduce it as much as possible. Among the helpful principles one might follow are the following.

A. Extensive practice of a complex movement may be expected to lower reaction time preceding the movement.

B. Teaching the athlete important cues just prior to the start of an action may lower reaction time. The change of tone of the quarterback's voice while calling signals just before the snap, the tension in the hand of the starter in tract, these are examples of some of the cues that might be attended to. Conducting a basketball scrimmage with whistless to signal fouls is more productive than not doing so, relative to the speed of reactions elicited under game conditions when the same sound is present.

C. Research has demonstrated that what the athlete has his mind "set" upon while waiting to move will exert a significant influence upon the quickness with which he initiates the movement, i.e., will raise or lower his reaction time.

D. Fllexing the muscles in the limbs to be moved (or in the total body) lower reaction time. A moderate amount of tension or too little tension. The athlete must experiment to find the correct tension.

4. To improve a task involving movement speed, it is important to allow the athlete to practice the whole act under the speed stress expected of him in competitive conditions. That is, one should attempt to overload the limb with resistance while sacrificing the terminal speed hoped for as little as possible. Movement speed may be improved by various kinds of perceptual training technique. It may also be improved in direct and indirect ways through strength training. One should first determine what muscle groups acts as stabilizers for the movement. When these muscles are strenghtened they will provide a more stable base from which to initiate the movement (3: 33-34).

5. To improve the sprint speed you may follow one of these two categories:

A. Sprint resisted training in which sprint running is stimulated with added resistance, the effort being to improve the dynamic strength factor, uses devices such as uphill running and weighted clothing.

B. Sprint assisted training where the effort is directed toward improving the rate of leg alternation uses downhill running, towing behind an auto at velocities above maximum unassisted and treadmill running at supramaximal rates (13: 427).

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